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ORDINARY MEETING.

17 December, 1940.

SIR LEOPOLD HALLIDAY SAVILE, President, in the Chair.

The Council reported that they had recently transferred to the class of

Members.

Clement Spencer Bainbridge.
Basil Ian Palmer, B.Sc. (*Durham*).
Charles Ross Wallace.

And had admitted as

Students.

Allen William Frederick Abbott.
Maurice Aiton.
Ratnam Alexander.
Henry Desmond Fitzmaurice Amor.
Peter Anthony Andrew.
Wilfrid Garrett Atkinson.
Arthur Bannister, B.Sc. (*Leeds*).
Earl Walshaw Bateman.
Reginald James Bell.
Patrick Arthur Browne.
Graham Buttler.
Leonard James Colyer.
John Fothergill Crosfield, B.A. (*Cantab.*).
Victor James Curchod.
Stephen Barrass Dracup.
Frank Kay Emerson.
Petrus Jacobus Fick.
Vernon Forshaw.
Reginald James Green.
Philip Harold Griggs.
Francis Terence Langford Guilbride.
Brian Hilliard.
John Charles Holohan, B.E.(*National*).
Peter John Hubble.
Frederick Walter Hunt.
David Cameron Lindsay.
John Percy Guthrie Scott McHutchen.
Daniel Angus Lochray McLarty.
Laurie Michelow, B.Sc. (*Witwatersrand*).
James Young Milne.
Trimbak Bhaskar Modak, B.Sc. (*Bombay*).
Robert Hugh John William Morton.
John Arthur Newton, B.Sc. (*Leeds*).
Robert Harry Pill.
Eugene Kingsley Rolls.
Grahame Shaw.
Irvine Smith.
William Alexander Smith, B.Sc. (*St. Andrews*).
Denis Taylor.
William Niven Thom.
Roland Berkeley Thorn, B.Sc. (Eng.) (*Lond.*).
Desmond Anthony Venner.
Donald Miller Watson.
Peter Gilbert Willmore.

The Scrutineers reported that the following had been duly elected as

Associate Members.

STANLEY RAYMOND CHETWYND ARCHER, B.S., (*Glas.*), Stud. Inst. C.E.
IAIN MACKINTOSH BAIN, B.Sc. (*Edin.*), Stud. Inst. C.E.
THOMAS ARCHIBALD CAMPBELL BROWNLIE, B.Sc. (*Edin.*), Stud. Inst. C.E.
RUPERT ARTHUR GEORGE EVELEIGH, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
JOHN ANGUS FOX, Stud. Inst. C.E.
JOHN HAYES, B.Sc. (*Manchester*), Stud. Inst. C.E.
STANLEY EDWARD JEWKES, Stud. Inst. C.E.
MICHAEL VIVIAN KEELAN, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
JOHN THOMAS LEWIS, Stud. Inst. C.E.
GEORGE CHARLES MANDER, B.Sc.(*Bristol*), Stud. Inst. C.E.
GERALD ERNEST MARSHALL, B.Sc. (*Durham*), Stud. Inst. C.E.
ROBERT BROWNLEE MASTERTON, B.Sc. (*Edin.*), Stud. Inst. C.E.
HENRY OLIVIER, B.Sc. (*Cape Town*), Stud. Inst. C.E.
RAYMOND POWNALL, B.A. (*Cantab.*), Stud. Inst. C.E.
KENNETH POYTON, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
JOHN HARTLEY ROBERTS, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.

The following Paper was submitted for discussion, and, on the motion of the President, the thanks of The Institution were accorded to the Author.

Paper No. 5251.

"The Mohammad Aly Barrages, Egypt." †

By Alec George Vaughan-Lee, M. Inst. C.E.

TABLE OF CONTENTS.

The Delta Barrage.

Historical.

This famous work, which consists of two barrages, one across the Rosetta branch and the other across the Damietta branch, is situated at the southern apex of the Delta and commands the whole of the water-supply for the irrigation of Lower Egypt, or the Delta.

The history of this barrage is very interesting and the vicissitudes through which the work has passed since its construction are many.

It is said that when Napoleon Bonaparte occupied Egypt in 1798 and 1799 he conceived the idea of constructing a barrage at this site, but it was not until 1833, when Mohammad Aly, the Viceroy of Egypt, gave instructions to commence a barrage on each branch of the river about 7 kilometres below the present site, under the direction of Monsieur Linant, that any progress was made with the scheme; but after about 2 years the works were abandoned and dismantled.

In 1843 a project prepared by Monsieur Mougel was accepted by the Viceroy, and this is, in substance, the barrage which now exists. The Damietta barrage was commenced first, and as few difficulties were experienced, this work is believed to have been fairly well executed. The Rosetta barrage was begun in 1847, but serious difficulties were encountered owing to the depth of water, springs in the foundations, slips, etc. These, in combination with hasty construction and the deposition of lime concrete on top of a rubble bank in running water, were the cause of the foundations being unreliable and the floor unsatisfactory. Nevertheless, the works were continued, and were practically completed in 1861. The gates in the

† Correspondence on this Paper can be accepted until the 15th June, 1941, and will be published in the Institution Journal for October 1941.—Sec. Inst. C.E.

Rosetta barrage were first closed in 1863, and the water-level upstream was raised slightly; this had serious results, sand being forced out from below the floor, and cracks appearing in the structure. In 1867 a length of about ten vents at the west end of the Rosetta barrage settled and moved bodily downstream. At that time the Damietta barrage had not even been fitted with sluice-gates.

The problem of putting the barrages in order and making them serviceable formed the subject of many commissions of inquiry and reports by engineers; but nothing appears to have been done until 1884, when gates were fitted to the Damietta barrage and it was regulated for the first time. In 1885 slightly more head was imposed on the two structures, namely 3 metres on Rosetta, and 1·75 metre on Damietta. The Rosetta barrage then showed signs of failure, and after thorough examination of the Rosetta floor by laying bare a considerable length inside a dam, it was decided to thicken and lengthen the floors of both works. This was done between 1887 and 1890, at a cost of about £E465,000*. In May 1891, with a 3·18-metre head of water on the Damietta barrage, large springs appeared on the downstream side and it was found that water was passing under the floor from upstream; but after considerable trouble the works were ultimately stanched. Although the barrages were now functioning, they could not be regarded as entirely sound and satisfactory structures, and small springs were observed every year on the downstream side of both works, indicating imperfections in the foundations. Therefore, in 1896, consideration was given to the possibility of stock-ramming the underside of the floors of both works with clay through holes drilled down through the superstructure. This expedient was tried in the same year, but it did not prove successful, as the clay would not spread out beneath the foundations. It was then decided to use cement grout under pressure from the natural head due to the height of the masonry structure, and holes were drilled down through the piers for this purpose throughout the full extent of the two barrages. A full account of these grouting operations, as well as of the weirs mentioned below, was given by Sir Robert Hanbury Brown, M. Inst. C.E.[1] This work was carried out in 1896, 1897, and 1898, and cost about £E6,000.

The bore-holes put down for the grouting operations disclosed so many defects in the lower layers of the concrete floors of the barrages that it was deemed necessary to construct a weir downstream of each work in order to raise the water-level immediately downstream of the barrages, thus reducing the head on the structures. The weirs were commenced in March 1898, and were completed in May 1901. Each weir has a navigation lock. The cost of these weirs and locks was about £E434,000. Their

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* £E1 = £1 0*s*. 6*d*.

[1] "The Use of Cement Grout at the Delta Barrage in Egypt." Minutes of Proceedings Inst. C.E., vol. 158 (1903–4), p. 1.

effect was that the maximum head on the two barrages was reduced to 3·00 metres, with a water-level upstream of +15·70 metres, the crest of the weirs being 12·70 metres above mean sea-level at Alexandria, which is the Ordnance Datum of Egypt and the Sudan.

Proposals for New Barrages.

The Egyptian Government, having in view the additional water for irrigation purposes that would be obtained from the second heightening of the Aswan dam, and also from the Gebel Aulia dam in the Sudan, contemplated the revision of the distribution of water in the Delta, for which purpose it would become necessary to pass more water down the three main canals taking off at the Delta barrage. In order to effect this, it would be necessary to impose more head on the two old barrages, and some doubt existed whether this could be done without risk to the structures.

The Minister of Public Works therefore appointed a committee early in 1933, to examine and report on the structure of the barrages, and this committee, which consisted of three engineers attached to the Egyptian Irrigation Service, reported in May 1933. The state of affairs disclosed in their report was far from satisfactory. The superstructures and piers appeared to be fairly sound, although there were cracks in nearly all the arches. New sluice-gates were required throughout, and also new machines for operating the gates. Bore-holes drilled through the existing floors had revealed that the lime and homra concrete in the lower layers of the foundations was more or less disintegrated, probably owing to large quantities having been deposited in running water. The most disturbing feature was in connexion with the eastern portion of the Rosetta barrage, where it had been founded originally on a tipped rubble bank. The borings proved that the grouting operation undertaken in 1896 to 1898 had not consolidated the rubble bank tipped to form a base for the barrage, and that the grout had not penetrated into the rubble as expected. The maximum depth of penetration found was 2 feet 8 inches below the bottom of the floor, and beneath the layer of grout the interstices in the rubble appeared to be quite free of solid material.

The Author's firm was requested by the Egyptian Government to study the committee's report and examine the existing structures. In the firm's report, dated the 15th January, 1934, the history of the barrage and the vicissitudes through which it had passed were recounted, and a recommendation was made that the Government should decide whether to run the risk of reconditioning the old structures or to build two new barrages downstream of the old ones.

Very wisely, the Government decided to adopt the latter alternative, and the Council of Ministers submitted a law to Parliament early in June 1934, for the construction of the new barrages under the name of the Mohammad Aly barrages. This law was approved on the 2nd July 1934,

and the Author's firm received instructions to proceed immediately with the preparation of the designs and contract documents for inviting tenders. The documents were ready in November 1935.

Tendering.

The Egyptian Government advertised for tenders on the 9th December 1935, and offers were received from nine British and three French firms. German firms did not submit tenders, although two of them paid the required preliminary cash deposit and inspected the papers. The original program in connexion with the tenders was to open them early in April and award the contract in May. This would have given the successful tenderer at least 6 months in which to organize his staff, plant, and supplies of materials, ready to begin a full season's work in December 1936, after the annual flood. Tenders were opened in Cairo, on the 7th April 1936, and they ranged from £E2,376,000 to £E2,949,000. A recommendation to let the contract to Messrs. Gibson & Pauling was made by the Ministry of Public Works to the Council of Ministers, and a decision had nearly been arrived at when the death of His Majesty King Fouad I occurred on the 28th April. A change of Government then took place and it was not until the 30th October that the contract was awarded to Messrs. Macdonald, Gibbs & Co. (Engineers), Ltd., with instruction to commence the works at once. Thus, 6 months' delay had occurred, which was very unfortunate, since the shortened period for organizing plant, staff, and materials, handicapped the Contractors in commencing the first season's work.

Description of the Works.

Extent of Works.

The work included in the scheme for the Mohammad Aly barrages was not confined solely to the construction of two new barrages downstream of the old Damietta and Rosetta barrages, but also included several works (Fig. 1, Plate 1), some of which might be described as of major importance. The following were the principal items :—

(*a*) Reconditioning the Tewfiki regulator and lock.
(*b*) The new Damietta barrage, with the navigation lock at its east end.
(*c*) An abutment at the west end of the Damietta barrage and a retaining abutment in connexion with the old Damietta barrage.
(*d*) The Hydraulic Research Laboratory.
(*e*) A swing-bridge across the Menoufia canal.
(*f*) The reconditioning of the ancient gateway of the fortifications.
(*g*) A new intake and a new regulator for the Nagayel canal.

(*h*) The new Rosetta barrage, with its abutment and the navigation lock at its west end.

(*j*) The new diversion for the Behera canal, with a new regulator and navigation lock.

(*k*) About 4 kilometres of roads, including two bridges over small canals.

(*l*) Steel and ironwork in sluice-gates, lock-gates, swing-bridges, operating-machines, sluice-valves, fittings, etc.

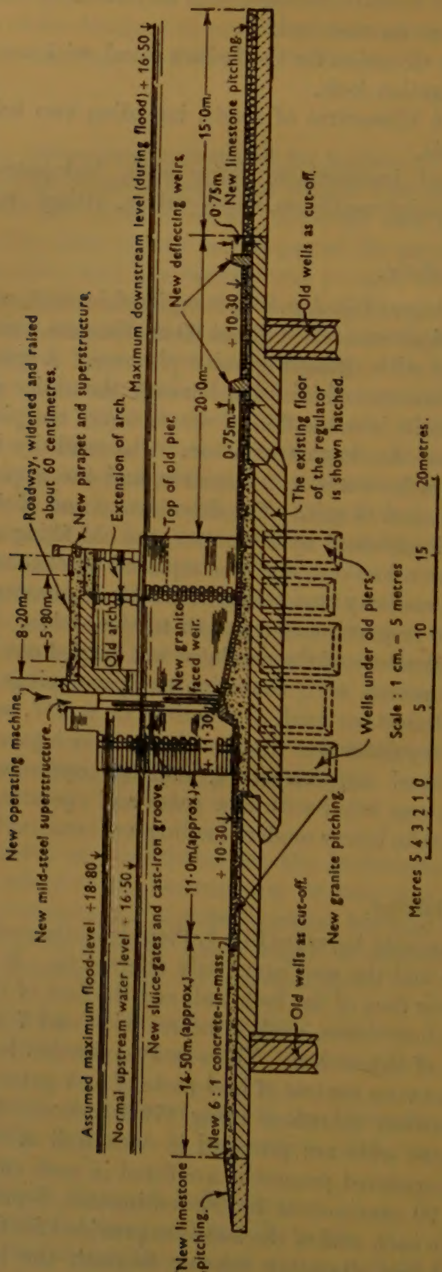
The Tewfiki Regulator.

This old regulator (*Fig. 2*, p. 242) completed in 1889, was reconditioned. The impervious floor was raised about 60 centimetres, and the greater portion was covered with dressed granite pitchers. A granite weir 1 metre in height was constructed directly beneath the sluice-gates. A granite baffle weir was built into the floor downstream of the piers, and a granite deflecting weir on the downstream toe. The roadway between parapets was widened from 5 metres to 8·2 metres, and the upper portions of the piers were lengthened to suit. The downstream end of the east guide-wall of the lock was lengthened by 10 metres, the old filling over the arches of the regulator was taken out, and was replaced by concrete-in-mass, whilst the level of the roadway was raised about 60 centimetres with mass concrete in order to impart more strength to the arches. The work on the piers and superstructure of the regulator was carried out with locally-made bricks, and the quoins, arch voussoirs, parapet copings, etc., were of the special *Shawish* limestone used, as described on p. 247, *post*, for the ancient gateway. The regulator was fitted with new sluice-gates, cast-iron sluice-gate grooves, steel superstructure, and an operating-machine. The navigation lock was fitted with new gates and operating-gear, and a new swing-bridge to take heavy modern loading was constructed across the lock.

The Damietta Barrage.

The new Damietta barrage (Fig. 1, Plate 1) is situated half-way between the old barrage and the weir previously referred to. It is 357 metres long between the river face of the lock-wall and the face of the west abutment, and has thirty-four vents, each 8 metres wide and 7 metres high to the springing level of the arches. There is a navigation lock 12 metres wide by 80 metres between centres of heel-posts of lock-gates, the overall length of the lock between entrances being 179·5 metres. Culverts 1·8 metre high and 1 metre wide are provided in each wall of the lock, and three cast-iron hand-operated penstocks are fitted in each culvert. Four filling culverts, each 90 centimetres by 70 centimetres, branching off from the main culverts in each wall of the lock, are provided for filling and emptying purposes. A 4-foot diameter subway beneath the lock accommodates service mains. The overall length of the barrage over lock and abutment

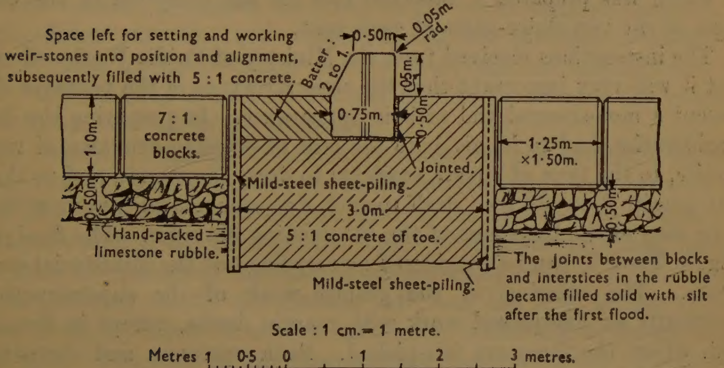
Fig. 2.



THE TEWFIKI REGULATOR.

is 406·45 metres. On the east bank of this branch of the river the land- or guide-wall of the lock was continued upstream until a junction was effected with the east wall of the navigation lock in the old barrage. Downstream of the lock the land-wall was stopped short, and the protection of the river bank was carried out in limestone pitching, built in mortar, to join up with the east wall of the navigation lock in the weir. This modification of the original design was due to the bad foundation and to the risk of damage to the existing lock at the weir, which might have been caused by the construction of a solid masonry wall in proximity thereto. The impervious floor of the barrage (Figs. 3 and 4, Plate 1) consists of 7 : 1 concrete-in-mass, 60 metres in width, with a line of mild-steel sheet-piling 3·5 metres long at the upstream and downstream extremities. There are two cut-offs beneath the floor of the barrage, situated beneath the upstream and downstream

Fig. 5.



extremities of the piers. Each cut-off consists of two lines of mild-steel sheet-piling 7·3 metres in length, spaced 1·5 metre apart; the sand between the piles was excavated by a small sand-pump to a depth of 5 metres below the bottom of the floor, and the space was filled with 5 : 1 concrete-in-mass deposited through water in hopper-bottom skips. The mild-steel piling used throughout the permanent work was of the joist-and-clutch section, the joists being 15-inch by 5-inch by 39·5-lb., and the clutches 15·6 lb. per foot run. Special cruciform or T-piles were provided at all crossings and meetings, and also at changes of direction unless the latter were very slight alterations in the line. Upstream from the impervious floor is a concrete blockwork apron 10 metres in width, and downstream a similar apron 15 metres wide. Downstream of the latter apron is a heavy concrete-in-mass toe 3 metres wide, deposited between two lines of 6-metre mild-steel sheet-piling. On this toe is situated a granite deflecting weir (*Fig. 5*), whilst downstream of this is a protective apron 10 metres in width,

consisting of concrete blocks each 1·5 metre by 1·25 metre by 1 metre deep, of 7 : 1 concrete, weighing about 4½ tons, set dry and close-jointed on a bed of handpacked limestone rubble about 50 centimetres deep. The piers of the barrage (Figs. 6, 7, and 8, Plate 2) are 22·6 metres long by 2·5 metres wide, and are faced entirely with granite. The upstream cut-water and the downstream tail are built of fair-picked granite ashlar, and fair-picked granite quoins are provided at the stop-log grooves and the sluice-gate recesses. Elsewhere the piers are faced with fine rock-face dressed-granite blockers laid in Flemish bond. The hearting of the piers is 6 : 1 concrete-in-mass. The courses of ashlar are generally 40 centimetres in height, and two courses of blockers go to one course of ashlar.

The floors of the vents between the piers are paved with rock-faced dressed granite pitchers, 40 centimetres deep, every sixth course being a header course. The sill-level of this barrage is at +12·00, and the actual sills beneath the sluice-gates are formed by a course of fine dressed granite, on which was prepared a fine-axed face for the reception of the bottom edges of the two sluice-gates of each vent.

The instructions received from the Ministry of Public Works stipulated that it was very important that the superstructure of the barrages should present a monumental and artistic appearance. In preparing the design, consideration had to be given to the cost of dressing ornamental work in granite, to the type of labour available to dress the stones, and to the fact that granite does not lend itself to such fine ornamental carved work as is to be seen in the limestone of the old existing barrages. The final design (Fig. 6, Plate 2) can be considered as carrying out the Ministerial requirements. The dressing of the granite work of the superstructure is practically all fine-picked work with margin drafts, except in the sluice-well, where the faces are fair-picked. Both upstream and downstream, semicircular bastions are provided at every fourth pier, and the intermediate piers have rectangular pilasters. At the abutment and on the river-wall of the lock are special large ornamental bastions, and on these and the smaller bastions are ornamental lamp-posts, each carrying two lamps. A swing-bridge suitable for modern loading is provided for vehicular traffic over the lock, and the tail end abutment thereof is formed by a granite-faced structure, containing two lock-up stores with steps leading down from the high-level roadway to the lock-walls. The design of the facing of these stores is in keeping with the design of the superstructure of the barrage, and the structure forms a retaining wall for the embankment of the roadway approach to the barrage.

In the barrages and large regulators in Egypt it has been found that, owing to the wide range of temperature, expansion cracks exist in most of the 5-metre arches of which such structures are usually built. In view, therefore, of the increased span of 8 metres adopted for the Mohammad Aly barrages, an interesting innovation was introduced in the design. On the top of each pier a division-wall of mass concrete 1 metre in thick-

ness, with skewbacks at its base, was first formed for the full width of the roadway and its parapets, and also at the flying arch. The sides of these division-walls were greased and against them the arches were turned and the concrete-in-mass spandrel filling was deposited; in this manner, with the exception of the abutments, a construction joint was formed at the end of each arch which would thus be free to "breathe." On the outside faces of the parapets the vertical lines of the expansion joints are concealed behind the upstream and downstream bastions and pilasters, but they are visible on the insides of the roadway parapets. Expansion joints were also provided in the walls of the locks and abutments, fitted with bent sheet-copper seals.

The roadway is 6·2 metres (20 feet 6 inches) wide between the granite curbs, and a footpath is provided on one side; both are paved with asphalt bricks, 5 centimetres thick, made in Alexandria. Conduits are provided under the road and footpath, for water, electric light, electric power, and telephone mains. Hydrants are fixed on the water-main at intervals for washing-down purposes, and rubbish-shoots are provided beneath the footpath curbs for the discharge of road sweepings and drainage into the river. The roadway is laid with a fall of 1 in 62 towards the rubbish-shoots under the curb of the footpath.

The Damietta Abutments.—At the west end of the Damietta barrage (Fig. 1, Plate 1) is an abutment about 112 metres long, which includes the return walls. A half-pier is incorporated in the wall for the reception of the western arch of the barrage, and flights of steps are provided, leading down from the high-level roadway to the abutment walls. A set of boat-steps is provided on the downstream side, and the inlet to the by-pass culvert of the Hydraulic Research Laboratory is situated in the upstream return-wall. The walls of this abutment are constructed in 7 : 1 concrete-in-mass, faced with granite blockers in Flemish bond, having fine-dressed granite quoins at all salient angles. The foundations are entirely surrounded by mild-steel sheet-piling, and the cut-offs of the barrage are carried across the foundations to the back line of the abutment wall, the upstream by the standard section of the barrage cut-off and the downstream by a diaphragm of mild-steel sheet-piling.

The old Damietta barrage originally consisted of seventy-one vents, sixty-nine of which were 5 metres wide, whilst two were 5·5 metres in width. Many years ago, it was found that the western ten vents were redundant, and they were filled up. The next ten vents towards the east silted up, and when the new barrages were designed, it was decided to block up these ten vents and construct a retaining abutment (Fig. 1, Plate 1), leaving fifty-one vents in the old barrage. The subaqueous portion of this abutment was constructed in 5-ton blocks, set by divers, as it was not deemed advisable to dry off the foundations and use concrete-in-mass, on account of risk to the old structure. The superstructure is faced with 5 : 1 small pre-cast concrete blocks backed with 7 : 1 concrete-in-mass.

The front wall of the abutment is formed by one of the piers backed with blockwork below water-level and with concrete-in-mass above. The two wing walls had to be of considerable length to form abutments or stops for the pitched slopes of the river-bank.

Those portions of the west bank of the river situated between the old barrage and the weir downstream of the new barrage that are not occupied by new masonry works are pitched with limestone rubble, mostly being built in 4 : 1 cement mortar.

The Hydraulic Research Laboratory.—The new Hydraulic Research Laboratory on the west bank of the Damietta branch (Fig. 1, Plate 1) replaces the old Hydraulic Station situated immediately downstream of the old barrage, which has been put out of action by the construction of the new barrage. The main intake is situated half-way between the two Damietta abutments, and consists of a granite-faced concrete wall containing two 2-metre-diameter cast-iron bell-mouthed hand-operated sluice-valves, serving two reinforced-concrete pipes, each 2 metres in diameter, which discharge into a small experimental canal, about 300 metres in length, leading through a 3-metre by 3-metre penstock to a concrete control-chamber. For the supply of water to the laboratory when the canal is in use for experimental purposes, a by-pass inlet culvert consisting of a 2-metre-diameter reinforced-concrete pipe, controlled at the intake by a 2-metre-diameter sluice-valve, runs from the Damietta abutment to the control-chamber, where the lower end of this by-pass is controlled by a 2·75-metre by 2-metre bell-mouthed penstock. From the control-chamber water flows into the laboratory buildings through a 1·2-metre-diameter cast-iron bell-mouthed sluice-valve, and thence through a reinforced-concrete pipe of the same diameter, in connexion with which a Venturi meter has been provided. From the control-chamber, as far as the main sump, a concrete flume about 4 metres by 4 metres, controlled by a 3-metre by 2-metre penstock, has been built for experimental purposes. The main laboratory building, which is not yet constructed, will consist of a large hall about 48 metres by 15 metres, and will contain a stilling-tank and two large flumes, with other apparatus. Attached thereto will be an administration building containing artesian wells, pumps, tanks, workshops, model-rooms, offices, etc. The discharges from the laboratory building are all led into three measuring-tanks of various sizes, controlled by cast-iron penstocks, discharging into the main sump, whence the water is returned to the Nile below the weir through the main outlet, which consists of two 1-metre-diameter reinforced-concrete pipes controlled by two cast-iron sluice-valves of the same diameter. The reinforced-concrete pipes were manufactured by the Siegwart process at works close to Cairo; all the sluice-valves and penstocks were supplied by Messrs. Glenfield & Kennedy, Ltd., of Kilmarnock.

The Menoufia Bridge.

The Menoufia canal, which supplies irrigation water to the middle triangle of the Delta, is crossed by a skew swing-bridge. This bridge was designed by the Ministry of Public Works, and its construction was let as a separate contract. It has a central circular pier founded on timber piles, and a central swing-span with two fixed side-spans, the outer ends of which are supported on piers built in the bed of the canal. The piers and abutments were constructed during the "closure" period, when the canal was closed for silt clearance from the 21st December 1938, until the 10th February 1939.

The Ancient Gateway.

This gateway, which is on the line of the main road between the barrages, is a relic of the old fortifications surrounding the Delta barrage (Fig. 1, Plate 1) and is a handsome brickwork structure having local limestone quoins and a very ornamental limestone superstructure with turrets at the western two corners. There are two archways, between which the old guard-rooms are situated; at the western end provision was also made in both archways for actuating drawbridges across the moat. The old structure was in a bad state of repair, and it was decided by the Ministry that it should be reconditioned throughout, and that a length of about 40 metres of typical section of the old earthen fortifications should be reconstructed on each side of the gateway. The work entailed the supply of a considerable quantity of new limestone ashlar, some of which was carved to match the existing ornamentations, the cutting out and replacement of some of the dressed stonework, and the provision of a concrete base and a new granite-paved roadway through each archway, with suitable footpaths and granite curbs. The whole of the old brickwork was repointed, and the slopes of the earthen fortifications were faced with limestone mosaic pitching. The dressed limestone was of a special hard and dense quality called *Tabaket Ahgar el Shawish*, obtained from quarries at Tourah, a few miles south of Cairo, whence the stone for the outer smooth facing of the pyramids is said to have been obtained. The quarries are in huge artificial caves or tunnels running into the hills and are very extensive. This stone is a hard and compact limestone, and though it is difficult and expensive to quarry, it can be well and easily dressed.

The Nagayel Regulator.

This small regulator (Fig. 1, Plate 1) is situated between the ancient gateway and the east abutment of the Rosetta barrage, and controls a small canal which irrigates about 30,000 acres of land. The main roadway connecting the new barrages crosses the regulator, and as it was considered

undesirable to diminish the width of the road, the new regulator is rather out of proportion for the actual requirements of a structure suitable for such a small canal and such a low head of water.

It is constructed on a 7 : 1 concrete-in-mass raft, which is surrounded by continuous mild-steel sheet-piling which also acts as an upstream and downstream cut-off 5 metres below the bottom of the floor ; there is also a line of 3 metres of steel sheet-piling across the floor parallel to the axis of the roadway for construction purposes, but which also serves to prevent water from creeping under the floor. There are two vents, each 3 metres in width, which are partially closed by a curtain-wall resting on a special mild-steel beam, against which the upper sluice-gate is stanched, thereby reducing the clear openings to 4 metres in height. The construction of this regulator follows lines similar to those of the barrages, being formed of mass concrete faced with granite blockers. The cutwater and tail to the pier, all quoins, steps, ramps, and ornamental superstructure, are built in fine dressed granite. In connexion with this regulator a new intake was provided about 200 metres upstream of the axis of the Rosetta barrage, the side slopes of this short length of canal being pitched with limestone. The original intake, which was at the intake of the Menoufia canal, about 1,000 metres upstream, has been closed.

In order to construct this small regulator it was necessary to divert the Nagayel canal, for which purpose the Contractors formed the diversion on the west side of the old canal.

The Rosetta Barrage.

The Rosetta barrage, containing forty-six vents, each 8 metres in width, is 483 metres in length between the face of the east abutment and the river-face of the lock-wall, and 533 metres long overall. It is situated about half-way between the old Rosetta barrage and the old weir (Fig. 1, Plate 1), the distance between which is about 1,600 metres. The design of the Rosetta barrage (Fig. 4, Plate 1, and Fig. 9, Plate 2) is very similar to the design of the Damietta barrage (p. 241, *ante*) ; but the abutment is on the east bank and the navigation lock on the west bank. Both barrages are designed for a head of 3·8 metres with an upstream level of +16·50 and a downstream level of +12·70, which latter is the level of the crest of the old weirs on the downstream side. This head gives, in both cases, a hydraulic gradient of 1 in 24. The most important differences between the designs of the two new barrages are as follows :—

The sill-level of the Rosetta barrage (+11·00) is 1 metre lower than that of the Damietta barrage, whilst the levels of the upstream and downstream toes of the former (+9·50) are 0·5 metre lower than the toes of the latter ; consequently, the slopes of the upstream and downstream impervious floors and aprons vary, those of the Damietta barrage being rather steeper. Except for the variation in levels and inclinations, the designs of the floors,

aprons, cut-offs, toes, etc., are similar. The granite-faced piers in both barrages are alike in detail, except that the Rosetta piers and vents are 1 metre higher than the Damietta; the superstructure, road levels, etc., are identical in both works.

The east abutment of the Rosetta barrage (Fig. 1, Plate 1) is practically similar to the abutment of the Damietta barrage; but both return-walls of the former are inclined at 45 degrees to the axis of the barrage. Upstream and downstream of the abutment, the east bank of the river was re-aligned, involving the removal of about 330,000 cubic metres of material. This bank was pitched with limestone rubble for the whole distance from the old barrage to the weir, except where satisfactory pitching already existed immediately downstream of the old barrage.

The navigation lock of the Rosetta barrage is similar in design to the Damietta lock, except that the lock-gate sills and the floor are 1 metre lower. The land-wall of the lock, however, has return-walls instead of guide-walls as at Damietta, and the slopes of the west bank of the river are pitched with limestone the whole way from the existing pitching in front of El Manashi village as far as the lock, and from the lock to the old weir.

In both barrages a line of transverse steel sheet-piling (Fig. 4, Plate 1) was driven beneath the floor and aprons, from the extreme downstream edge to the upstream edge of the protective blockwork aprons. This was intended to act as a water cut-off in connexion with the sudds required for the two seasons' work in the river-beds. The Damietta piling was used for this purpose, but at the Rosetta barrage the Contractors preferred to drive, at their own cost, another line of piling five vents farther to the eastward, as they had found that they could construct more than half the total floor during the season. In addition to these lines of piling it was found desirable to drive two more rows at the quarter and three-quarter distances between abutments, in order to confine the grouting operations beneath the floors to more limited areas, and to assist the Contractors' progress. The last-mentioned lines of piling, which extended only below the solid floor, were 3·5 metres in length, whereas the half-way piling was 5·3 metres in length. Where the half-way piling crossed beneath the blockwork apron, concrete-in-mass was substituted for the blocks for a width of about 4·5 metres, to provide a watertight seal. These lines of sheet-piling will be of considerable use should it be necessary at any future time to sudd off portions of the floors in order to execute repairs.

The Behera Canal and Regulator.

At the present time water-borne traffic from Alexandria to Cairo follows the Mahmoudia canal from Alexandria as far as the Rosetta branch of the river, and after navigating the latter for a short distance enters the Menoufia canal, traversing this waterway to the Delta barrage. The Menoufia canal is rather serpentine in its lower reaches, and on certain lengths the prevailing north wind is unfavourable for the sailing craft

which transport most of the goods, thus lengthening the voyages. It is the intention of the Egyptian Government to divert all of that traffic to the Behera canal, which, when its lower reaches are widened and reconditioned, will provide a shorter and straighter route from Alexandria to Cairo, and one more suitable for sailing vessels.

With this end in view, the Government decided to abandon the old Behera regulator at the Delta barrage, and to construct a new entrance to this canal having a new regulator which would provide for the larger discharge required for the reconditioned system of canals to their junctions with the Mahmoudia canal near the town of Damanhour.

The new Behera canal diversion (Fig. 1, Plate 1) at the Mohammad Aly barrages takes off about 500 metres upstream from the entrance to the old canal; it is 1,800 metres in length, joining the latter about 850 metres downstream from the old regulator. Upstream from the new regulator, the new canal has a bed-width of 84 metres, whilst below the bed-width narrows gradually from 84 metres to about 40 metres, which is the approximate bed-width of the old canal at the junction-point. Upstream from the regulator and around the noses of the entrance the side slopes are pitched with limestone rubble, whilst downstream from the regulator they are similarly pitched for a distance of 188 metres, measured from the axis of the new regulator, and also for a length of 500 metres on the concave side of the curve where the new diversion joins the old canal. All side slopes of the canal are 1 in 1½, and have two horizontal berms at suitable levels, ranging in width from 2 to 6 metres. For a short distance both upstream and downstream from the wing walls of the lock and the abutment of the regulator, the pitching is built in 4 : 1 cement mortar. The bed of the canal has not yet been dredged to its full depth, but the finished depths will be obtained when the whole Behera canal system has been remodelled. Materials from the excavations were utilized to fill the old canal, and adjacent ponds, and also to form approaches to the regulator, embankments, and roadways.

Before the design for the entrance to the new diversion was finally elaborated and decided on, complete experiments were carried out on a large-scale model to determine its best shape in order to minimize the deposit of silt and to produce a straight flow for the full width of the canal towards the regulator without the formation of eddies. These experiments were carried out by the hydraulic section of the Ministry of Public Works, under the direction of the Resident Engineer in charge of the old barrages.

The normal working head for the Behera regulator (Fig. 10, Plate 2) is 3 metres, with upstream and downstream water levels at +16·50 and +13·50 respectively. A worse condition occurs during the canal closure period, when the upstream level is +14·00, and the downstream dry, when the head is 3·5 metres. Under the latter conditions the hydraulic gradient is 1 in 24. The design adopted is similar to that of the barrages, namely, an impermeable floor of concrete-in-mass with blockwork aprons

upstream and downstream, and the solid concrete downstream-toe with granite deflecting-weir. With a view to economy, two lines of interlocking mild-steel sheet-piling were substituted for the double lines of piling and concrete-in-mass cut-offs of the barrages. The upstream line was continued beneath the floor of the lock, and the continuation of the downstream line was effected by the two lines of piling required for the construction of the subway beneath the lock. In each vent, however, directly beneath the sluice-gates, is a granite-faced weir 1 metre in height, the downstream slope of which is 1 in 5; the remainder of the floor and the aprons are level. The regulator is 63 metres in width between the abutment wall and the river wall of the lock, and includes six vents, each 8 metres in width. The details of the piers and superstructure are similar to those of the barrages, except that the piers of the regulator are 1·10 metre shorter than the barrage piers, whilst the level of the coping of the tails of the piers is at +17·00 instead of +19·00 as at the barrages.

There is a navigation lock 55 metres long between centres of heel-posts, and 12 metres in width, the overall length between entrances being 151·5 metres. The details of the lock throughout are similar to those of the barrage locks, with boat-steps, gauge-wells, ladders, ring bolts, culverts, penstocks, capstans, bollards, etc. The abutment of the regulator is similar in design to the barrage abutments, but it is considerably smaller and there are no boat-steps.

Roads and Surfacing.

The distance from end to end of the works is 5·1 kilometres, and of this about 1,300 metres is occupied by masonry and other works, leaving 3,800 metres of roadway (Fig. 1, Plate 1) to be constructed on low embankments about 1½ metre to 2 metres above the adjacent ground-level; most of this is level, but gradients are necessary at the approaches to the various masonry works, the steepest being 1 in 26. The side slopes of the embankments are 1 in 2, and are faced with dry limestone pitching for the greater part, but in some places the pitching is built in 4 : 1 mortar. The road is 10·6 metres in width, with a footpath 2·6 metres wide on each side with pre-cast concrete curbs; the base of the road consists of limestone rubble hardcore, well rolled and consolidated, surfaced with a coarse and fine layer of crushed basalt bituminous macadam of a total depth of about 4 inches, and the footpaths are surfaced with a 1-inch fine layer of the same material, all according to British Standard Specifications. Ample provision is made for drainage, lighting, and water-supply for cleansing. Portions of minor by-roads leading into the main road have also been re-formed and surfaced. The level surfaces at the backs of the walls of the locks, abutments, regulators, etc., are surfaced with 4 inches of crushed basalt chippings mixed with sand, well rolled, watered, and consolidated.

In addition to the above-mentioned roads, the Government constructed,

under a separate contract, a road about 500 metres in length, from the south side of the Behera regulator to join with the Cairo road alongside the railway on the west bank of the river.

On the main road between the Damietta barrage and the Menoufia canal, two small road-bridges cross the experimental canal of the Hydraulic Research Laboratory, and the small Darawa canal. Both are skew bridges, placed at an angle of 45 degrees, and have concrete-in-mass foundations surrounded by mild-steel interlocking sheet-piling. The abutments and wing walls are of 7 : 1 concrete-in-mass faced with granite blockers. These bridges have a span of 8 metres, measured on the square, and are constructed of reinforced concrete, there being nine beams and a heavy slab incorporated therewith. The full standard width of the main road and footpaths is preserved, the distance between the parapets being 14·6 metres ; the latter are of fine-dressed granite similar in design to the barrages, with ornamental pilasters at each corner.

Materials and Workyards.

Most of the materials, with the exception of iron and steelwork, which Egypt does not produce, were obtained in the country.

Granite.

As no hard stone suitable for dressing and for the facing of work exposed to constant water-action was obtainable in the neighbourhood of Cairo, it was decided to use granite from Aswan for this purpose. Before the contract was let, the Egyptian State Railways undertook to transport all granite for the works from the quarries at Aswan to the handing-over stations in the workyards at the barrages, a haulage of about 920 kilometres (572 miles), for 50 *piastres* (10*s*. 3*d*.) per metric ton, equal to 0·215*d*. per ton-mile. The granite was of the large-grained pink quality, and special quarries were opened to the north of Shellal railway-station and to the west of the Egyptian State Railway's main line, whence a siding was laid to the quarries. The quarry in the rear of Shellal railway-station was also used. All granite, with a few very minor exceptions, was dressed at the quarries by Italian and Egyptian stone-cutters ; a large number of the former had been previously employed in the Sudan in dressing the granite for the Gebel Aulia dam. During busy periods, 2,000 cubic metres of dressed stone was dispatched to the barrages every month, and 320 Italian and about 200 Egyptian stone-getters and stone-cutters were employed at the quarries, together with about 1,700 labourers. Most of the Egyptian stone-cutters were trained at the school maintained at Aswan by the Egyptian Government. The quality of the dressing of the granite was very good and for a large public work of this description could not, in the opinion of the Author, be surpassed for fineness, uniformity, beds, and joints.

Limestone.

This was obtained from the hills on the east bank of the river in the neighbourhood of Tourah, about 14 kilometres south of Cairo. It was transported to the site by river, and was used mostly for pitching banks, but some limestone of special quality was dressed at the site by Egyptian masons, and used as described for the ancient gateway.

Basalt.

The basalt for road-making, which is used extensively in and around Cairo for this purpose, was obtained at Abu Zabal on the Ismalia canal, about 25 kilometres north-east of Cairo, from quarries owned by the Mines Department and the Prison Authorities.

Ballast and Sand.

Gravel and sand were obtained from the low hills on the fringe of the western desert, where huge quantities are obtainable at a distance of about 15 kilometres from the site. Sidings were laid from the Egyptian State Railways to the pits, and the ballast and sand were worked by Decauville wagons from the pits into the State Railway wagons. The ballast was slightly impregnated with desert dust, and it was all washed and cooled before being passed into the concrete mixers. It was of excellent quality and well graded, and was situated in a layer about 2 metres thick on the surface. All of it was excavated by hand and screened by hand at the same time. The sand was large-grained, sharp, and clean, and did not require washing.

Cement.

All Portland cement for the works was manufactured at the Tourah and Helwan works of the Egyptian *Comptoir des Ciments*, at both of which modern up-to-date plant is installed. The ingredients consisted of crushed limestone from the Tourah hills, and deposits of Nile mud. The Tourah works supplied about 75 per cent. of the quantity used. The cement, manufactured to British Standard Specification, was tested and analysed at the works by representatives of Mr. R. H. Harry Stanger, Assoc. M. Inst. C.E., who were resident in Egypt during the construction of these works, the remodelling of the Assiut barrage, and the construction of the Gebel Aulia dam. Taking the average of every tenth consignment of 250 tons, the following results were obtained on the cement used at the Mohammad Aly barrages, which amounted to about 106,000 tons :—

Residue on 170 by 170 sieve : 6·1 per cent.
Residue on 72 by 72 sieve : 0·15 per cent.
Initial setting-time : 118 minutes.
Final setting-time : 180 minutes.

Soundness: expansion, 1·64 millimetres.
Tensile test (neat cement, 7 days): 1,163 lb. per square inch.
Tensile test (with sand, 3 days): 466 lb. per square inch.
Tensile test (with sand, 7 days): 523 lb. per square inch.

Workyards.

Two large workyards were established by the Contractors on land provided by the Government, one for the Damietta barrage, and one for the Rosetta barrage. A handing-over station was laid down in each yard by the Government, providing direct railway communication with the Egyptian State Railways. To obtain access to the Rosetta yard, the State Railways erected a temporary swing-bridge across the Behera canal before the commencement of the works. Each yard contained a block-making and stacking floor, granite ashlar yard, cement-shed, stone-crushing plant, and the usual Contractors' workshops, stores, etc. A subsidiary workyard was established close to the Behera regulator for the storage of cement, granite, and other materials.

Construction of the Works.

The actual execution of the works did not call for any exceptional methods, or for the provision of any special plant, provided that ample numbers of travelling cranes, concrete-mixers, and wagons were available. As in the case of all large public works, particularly those of a scattered nature such as these barrages and their subsidiary works, it was entirely a question of providing plenty of mobile plant in combination with good organization. The two barrages were favourably situated in comparison with earlier dams and barrages constructed on the Nile, as during the working season, from the commencement of February to the end of July, the old barrages upstream of the new works are practically closed down, and there is a very small discharge down both branches of the river, with practically none at Rosetta. The Contractors, therefore, had not to contend with the full summer flow of the Nile, which was passed down the three main canals that take off above the old Delta barrages.

The most serious difficulty encountered during construction arose in the first season of 1937, in connexion with the foundations of the Damietta lock, where a layer of black Nile mud 2 to 3 metres in depth was found just below the contract level of the foundations. The foundations of each lock are surrounded by mild-steel sheet-piling, and are divided by transverse pile diaphragms into four pockets. It was easy, therefore, to subdivide these four large pockets into smaller compartments by steel sheet-piling, to excavate the mud by hand down to the substrata of clean sand, and to refill the compartments with sand deposited in water to the level of about 1 metre above the foundation-level. This surplus filling was then excavated to the required depth, and the concrete foundations

of the lock were deposited at the contract level. This method produced a sand foundation equal to any exposed elsewhere on the works, and was entirely satisfactory, no signs of any settlement being discovered in the completed lock-walls. Similar difficulties were experienced, and similar remedial measures were undertaken, in the foundations of the upstream guide-wall of the Damietta lock. Another minor difficulty arose in the foundations of the Behera regulator and lock, where a similar layer of mud overlay the foundations, forming a source of trouble during excavation. The underlying sand was of excellent quality, but its surface was about 1 foot to 1 foot 6 inches below the contract foundation-levels. The foundations of the floor of the regulator, the lock, etc., were therefore taken down rather lower than was originally intended (Fig. 10, Plate 2), as the best and most economical solution of the difficulty.

The foundations as a whole were on Nile sand of excellent quality, and the infiltration water was less than has been noticed elsewhere on similar works on the river. The water in the foundations was dealt with in the usual manner, by means of earthenware pipes leading to sumps. These pipes were subsequently grouted under pressure through mild-steel standpipes, and the sumps were sealed, as was done at the Nag Hammadi barrage [1] and the Assiut barrage remodelling [2].

As stated on p. 240, *ante*, the delay due to the contract not having been awarded until the end of October 1936, was a considerable handicap to the Contractors, as it left them insufficient time to organize their staff and plant in readiness to commence work in January 1937. Fortunately, considerable quantities of second-hand plant were available from earlier works in Egypt at Aswan and Nag Hammadi, whilst other plant was obtained from Gebel Aulia, and sheet-piling for temporary purposes from Assiut. Most of the plant was driven by electric power obtained from the Shubra power-station, about 13 kilometres away, whence a special cable was laid to the works.

During the first season in 1937, the foundations of the Damietta lock were put in hand, and the Rosetta lock was completed to well above flood-level. During December 1937 and January 1938, the floor of the Tewfiki regulator was reconditioned. During the second season in 1938, the Damietta lock-walls and guide-walls were constructed, and the eastern half of this barrage was built, whilst the Rosetta lock was brought up to its full height, and the western twenty-eight vents of the Rosetta barrage were built. During the flood period of 1938, the Behera regulator, lock, etc., were put in hand, the necessary plant being available from the barrages. During December 1938, and January 1939, new sluice-gate grooves and sluice-gates were installed in the Tewfiki regulator, and work was commenced

[1] A. R. Ellison, "The Nag-Hammadi Barrage, Upper Egypt." Minutes of Proceedings Inst. C.E., vol. 232 (1930–31, Part 2), p. 340.

[2] J. E. Bostock, "Remodelling of the Assiut Barrage, Egypt." Journal Inst. C.E., vol. 14 (1939–40), p. 301 (June 1940).

on the new lock-gates of this lock. December and January are the only months in the year during which work can be executed in the beds of these main canals, as they are then closed down for silt-clearance and repairs. During the third season, 1939, the western half of the Damietta barrage and its abutment and the retaining abutment to the old barrage were completed, the eastern portion of the Rosetta barrage and its abutment were constructed, and the Behera regulator and lock were also completed. During these three seasons the minor and subsidiary works were executed from time to time as opportunity offered; these included the Nagayel regulator, the ancient gateway, the Hydraulic Research Laboratory, the road-bridges, the roads, the superstructure of the Tewfiki regulator, and the erection of the sluice-gates, lock-gates, swing-bridges, and operating-machinery. The works were substantially completed by the contract date (the 15th December 1939) and the barrages were used for regulation in February 1940, after the annual canal closure period.

Mechanical Equipment.

The provision of the sluice-gates, lock-gates, swing-bridges, operating-machines, penstocks, etc., entailed the placing of large sub-contracts, for which separate tenders were invited; the total value of these was £E320,000, erected in place. In addition a lump sum of £E20,000 was provided in the schedule of prices for payment to the main Contractors for services they had to render to the sub-contractors under the conditions of contract, such as the provision of workyards, housing, temporary dams, pumping, use of cranes, etc.

Messrs. Ransomes and Rapier, Ltd., were awarded the sub-contract for the sluice-gates, operating-machines, etc., and Messrs. Head, Wrightson and Co., Ltd., that for the lock-gates, swing-bridges, penstocks, etc. Messrs. Glenfield and Kennedy, Ltd., supplied valves, etc., for the Hydraulic Research Laboratory, whilst the fittings were purchased from various engineering firms.

The following Table gives the total weights and cost of the mechanical equipment:—

Table I.

	Weight: tons.	£E.
Sluice-gates, operating-machines, caterpillar crane, etc.	3,691	218,000
Lock-gates, swing-bridges, capstans, penstocks, stop-logs, etc.	2,049	102,000
Lump sum for main Contractors on account of services rendered	—	20,000
Valves, penstocks, etc., at the Hydraulic Research Laboratory	139	10,500
Fittings	641	35,500
	6,520	386,000

It is satisfactory to note that all of these large orders for mechanical equipment were placed in Great Britain, and that all deliveries were up to time, thus obviating any delay in completing and bringing the barrages and regulators into use by the dates anticipated.

General.

The specification laid down that the calculations for the sluice-gates should be based upon an upstream water-level of +16·50 with the downstream side of the gates dry, and those for the lock-gates upon an upstream water-level of +18·80, also with the downstream side dry. These requirements may appear to be very stringent, but they are desirable in the event of its being necessary to dry off a sluice-vent or a lock in emergency. The permissible maximum stress in the steelwork for the sluice-gates and lock-gates was 6 tons per square inch, to ensure ample provision for corrosion, whilst in the swing-bridges, etc., it was fixed at 7 tons per square inch. For a similar reason the minimum thickness of any rolled section or plate, except in the case of small beams and channels, was fixed at ½ inch ; in order to comply with this provision, the channels for the side-frames of the sluice-gates were specially rolled with ¾-inch webs, to allow for machining.

Sluice-Gates.

The sluice-gates throughout the work are of the fixed roller type, two gates to each vent. This is the usual arrangement in Nile barrages, the upper gate being placed upstream with its skin-plate facing downstream, and the lower gate being placed downstream with its skin-plate facing upstream (Fig. 7, Plate 2). This arrangement allows regulation either below the bottom gate or between the gates, according to water-level or requirements.

Table II below gives the principal particulars of the various sluice-gates.

TABLE II.

	Number of vents.	Width of vent: metres.	Sill-level: metres.	Total height of both gates: metres.	Height of one gate: metres.	Head for calculations: metres.	Normal working head: metres.
Rosetta barrage . .	46	8·00	+11·00	5·70	2·90	5·50	3·80
Damietta barrage . .	34	8·00	+12·00	4·70	2·40	4·50	3·80
Behera regulator . .	6	8·00	+11·50	7·00	3·55	5·00	3·00
Tewfiki regulator . .	6	5·00	+11·30	7·00	3·55	5·20	3·00
Nagayel regulator . .	2	3·00	+13·00	4·15	2·125	3·50	2·00
Total pairs of gates .	94	The upstream water-level is +16·50 in all cases.					

All of the 8-metre gates have skin-plates $\frac{5}{8}$ inch thick, riveted to rolled steel beams of special section which have their outer flanges entirely on the underside of the web, thus diminishing the deposit of silt and debris on the beams. A similar section used previously was too light for the 8-metre spans, and new rolls had to be made. The cost of the new rolls was not a large item when spread over the whole of the gates, since about 4 miles of the section was used; it was, in fact, lower than the cost of fabricated beams, besides being more satisfactory on other grounds. The beams are attached to the specially-rolled channel side-frames by cleats with fitted bolts, and the steel axle-castings are spigoted and bolted to the side-frames. The rollers are of Meehanite cast iron, 24 inches in diameter. The Rosetta and Behera gates have four, and the Damietta gate has three, rollers on each side of each gate. The treads of the rollers are slightly barrelled and they are bushed with bronze, with bronze sleeves on the axle castings; the two bronzes are of different compositions, as determined by experiments, to ensure satisfactory running together in silty water without lubrication. All fitted bolts in the gates are sherardized.

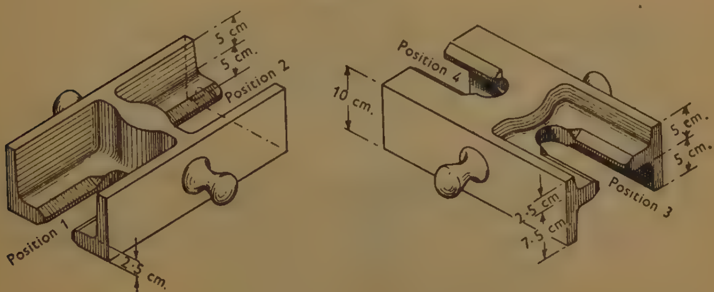
The space between the two gates in each vent to permit them to pass was fixed at $\frac{3}{8}$ inch, the minimum which it was thought advisable to allow, in view of the large surface of the gates and the possibility of irregularities in them and the grooves, although the greatest care was taken to ensure accurate surfaces. Each gate was checked over after manufacture, and no difficulty was found in working to a tolerance of plus or minus $\frac{1}{32}$ inch on the dimensions affecting the clearance of the gates.

The gates are stanched by means of machined rectangular bars; those at the sides are adjustable by means of eccentric bolts so that they can be set to suit the machined face on the groove castings against which they abut. The top and bottom bars are riveted to the gates, and the downstream or bottom gates have also a number of narrow intermediate horizontal bars; in connexion with these the upstream or top gates have a bottom stanching-bar or plate of sufficient width to cover the space between any two intermediate bars on the downstream gate, so that when the gates move past one another the leakage does not vary. In addition it was necessary to stop the leakage during the summer season, when there is no discharge except for a small flow in the Damietta branch to feed the Zifta barrage, 90 kilometres downstream. This was achieved by fitting horizontal bars to the tops of the downstream or bottom gates; when the barrages are closed down these bars can be pushed forward against the bottom stanching-bars of the upper gates and bolted. In the old barrages the sluice-gates were caulked with old rags every year to prevent leakage. When the side stanching-bars of the 8-metre gates were finally adjusted, an allowance of 2 millimetres was made at each end of each gate for expansion purposes.

The sluice-gates are lifted by short link chains made in pairs, with their links carefully matched and made to an exact pitch of 10 centimetres in

order to simplify the measurement of the gate-opening required for regulation. The chains are suspended from mild-steel spragging beams, the ends of which are recessed into the granite copings of the sluice-wells over the ends of each pair of gates; the spare ends of the chains are stowed on small chequer-plate covers spanning the sluice-wells. It was decided that finer regulation was required on the 8-metre gates than could be given at 10-centimetre intervals, and a cast-steel sprag (*Fig. 11*) was accordingly designed, which has four holding positions for the chain links and enables regulation by steps of 2·5 centimetres. Each sprag weighs 44 lb. and can be turned over easily by hand, being chained to the spragging-beams to prevent loss. Tests made on four sprags showed that they would carry loads of 25 tons before any permanent set took place.

Fig. 11.



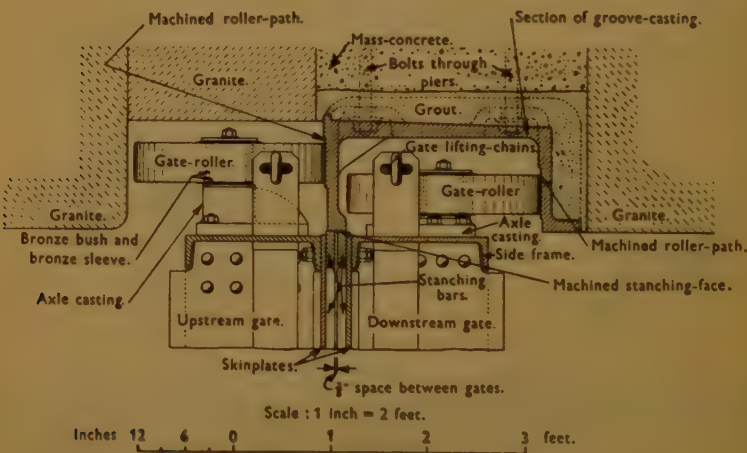
The smaller types of gates required for the Tewfiki and the Nagayel regulators were designed on lines similar to those of the large gates, but British Standard sections were employed for the beams, the top beam at Nagayel being a channel. The rollers at Tewfiki were four a side and 15 inches diameter, and at Nagayel three a side and 12 inches diameter; the other fittings, chains, sprags, etc., were on similar lines, but of smaller dimensions. In the Nagayel regulator the normal placing of the gates is reversed, the lower gate being in the upstream groove with its skin-plate facing downstream, and the upper gate in the downstream groove with its skin-plate facing upstream; the reason for this arrangement is that the upper gates carry an additional stanching-bar on the back of the top beam to stem leakage between these gates and the mild-steel beams supporting the concrete curtain-walls in the vents. Special castings are provided at the top of the upper gate to fit into the cast-iron grooves to stem the flow of water at high Nile down the groove, and to prevent wear and tear of the chains and rollers.

Groove Castings for Sluice-Gates.

The rollers of the sluice-gates travel on machined paths on iron castings built into recesses formed in the piers. All of the grooves for the 8-metre

gates are ⊔ shaped (*Fig. 12*) and the downstream flange of the casting, which is backed by masonry, carries the rollers of the bottom gate, which have the heavier loads, whilst the upstream unsupported flange carries the more lightly loaded rollers of the upper gate. The roller-path of the top gate is placed as near the inside of the casting as possible, in order to minimize the bending-load on the flange, the projecting end of which is accurately machined to provide a meeting-face for the stanching-bars of the sluice-gates. The castings at the side of each vent are divided into four lengths, three long and one short, the latter being double and embracing both grooves. The castings are of Meehanite cast iron throughout. One

Fig. 12.



of the first long castings produced was tested under a concentrated load by hydraulic pressure, the loading being on the line of the upstream roller-path; a load of 175 tons was applied before the casting commenced to crack. This result indicates an ample margin to withstand the heaviest loads that can be imposed on the grooves.

The castings were carefully machined from jigs to ensure interchangeability, and particular care was taken, when dealing with the ends of each casting, to avoid errors which would have caused distortion in the perpendicular alignment of each set of grooves. The three long castings of each set were erected together, and when fixed in position with the adjacent set on the other side of the pier they were all slowly grouted up. The respective sets on the sides of each pier were secured in position and to each other by 1½-inch-diameter galvanized through-bolts, for which cored holes had been formed to templet through the concrete hearting. At abutments lewis-bolts were used. Plumbing tests made with precision instruments to test the verticality of the grooves showed that any errors observed were so

minute that they could be ignored. This extremely exact erection reflects great credit upon the supervisory staff of the sub-contractors.

At the Tewfiki and Nagayel regulators the groove castings are of double section and line the whole of the recess in the masonry. At Tewfiki this was necessary in order to avoid difficult work in rebuilding the masonry on the upstream side of the recess after the removal of the old grooves, as the time available during the canal-closure period was very limited. At Nagayel it was necessary to ensure satisfactory spacing of the bolts securing the castings to the masonry. At the latter regulator the mild-steel beams on the underside of the curtain-walls are bolted to the groove castings, provision being made for the expansion and contraction of the beams.

Operating-Machines.

The operation of the sluice-gates is effected by machines travelling on the superstructures of the barrages and regulators; seven machines were required, those for the large gates being power-driven and the smaller ones operated by hand. On the two barrages the machines span the roadway and travel on 80-lb. flat-bottomed rails bolted to the granite 38 feet apart centre to centre. An overhead portal arrangement allows gates to be lifted clear of the sluice-well for transport to the workshops for overhaul. There are two such machines on each barrage, designed for a working load of 22 tons with the following speeds:

Hoisting full load	10 feet per minute.
Hoisting light load	80 ,, ,,
Cross-traverse of crab	20 ,, ,,
Longitudinal travelling	100 ,, ,,

The cross-traverse speed was kept low in order to avoid surging in the portal-frame due to movement of the crab.

Each power-driven machine has two 51-brake-horse-power petrol engines running at 1,200 revolutions per minute, either of which can work the machine while the other serves as a stand-by. A hydraulic coupling is fitted to each engine, and there is the usual train of gearing. Hoisting is effected by two wire-rope blocks, one for each end of a gate; the blocks have two parts of rope, one end of which is taken to the hoisting barrel and the other to a special anchor barrel; by the movement of the latter the loads on the two blocks can be equalized and the gate maintained level should the wire ropes stretch unequally. An automatic self-sustaining brake is fitted to the hoisting motion to prevent the load taking charge should the engine stall. The underframe is fitted with block brakes on four of its wheels, worked by hand-wheels at roadway-level, and chain ties with coupling screws are provided to tie up the machines at each end of the barrages. A speaking-tube runs from parapet-level to the driver's position, so that the banksman can give his orders to the driver, who stands on per-

forated floor-plates through which he can see the load. The machinery in the crab is enclosed in a roomy double-roofed sheet-steel house fitted with metal window-frames and doors, which also accommodates duplicate electric lighting sets for illuminating the house and the roadway.

The Behera regulator has one low-level power operating-machine of 9-foot 6-inch gauge running on the parapet walls of the sluice-well. This has the same loads and speeds as the barrage machines, but is incapable of placing a gate on the roadway. The chain hooks are the only special feature of interest. In low-level machines it is not always possible to give the hooks the total range of lift required, and therefore the hooks may have to engage the intermediate 10-centimetre links of the chains, as it is undesirable to introduce special links for this purpose. As the hooks must be of equal strength to the chains, an alloy steel containing molybdenum was used, tempered to give a yield-point of 60 tons per square inch with 20 per cent. elongation and a minimum impact value of 50 foot-lb. Careful tests were made on the material, during which a special test-hook withstood a load of 65 tons without opening or fracture.

The machines at the Tewfiki and Nagayel regulators are both low-level and hand-operated. The Tewfiki machine will lift 10 tons at a speed of 1 foot per minute with eight men on the handles. At Tewfiki the upstream rail of the machine is carried on steel girders spanning the sluice-vents; these, with the timber sleepers, rails, etc., were renewed, as the old materials had deteriorated badly during the 50 years they had been in place. The machine for the Nagayel regulator is of similar design and will lift 5 tons at a speed of 1 foot per minute with four men on the handles. Both of these machines are fitted with hooks of molybdenum alloy steel.

Caterpillar Crane and Trolley.

A crane running on caterpillar tracks is provided for handling stop-logs in the safety-grooves of the piers and for general work, possibly on soft ground. It will lift 4 tons at radii up to 33 feet, and is driven by a 51-brake-horse-power petrol engine identical with those of the operating-machines. Interesting features include the electrically-welded mild-steel base framework, the welded bed of the revolving superstructure, and the welded jib, introduced with the object of saving weight, as the maximum weight of the crane had to be kept low for crossing the swing-bridges. The actual weight of the crane was 29½ tons.

A mild-steel trolley for transporting sluice-gates was also provided. It is designed on the lines of a timber wagon and has rubber-tired wheels with ball bearings.

Lock Gates.

Each of the three large locks was equipped with mild-steel lock-gates having particulars and overall dimensions as shown in Table III.

The gates are all single-skin, with the plating on the upstream or curved side, ranging from ⅝ inch at the top to ¾ inch at the bottom. Each leaf is fitted with two levelling-sluices, with 3-feet by 2-feet clear opening, worked by hand. The downstream or flat faces have six or seven horizontal mild-steel T-fenders to avoid the use of timber, but the heel-posts, mitre-posts, and clapping-sills are of greenheart. The downstream or flat face has a 10-inch by ½-inch flat steel tie from the upper pivot to the foot of the mitre-post. Experience gained during the erection of these gates confirms the value of this tie, provided that it is not drilled or riveted until after the gates have been finally adjusted. On earlier single-skin gates there was a

TABLE III.

	Up-stream water-level: metres.	Sill-level: metres.	Level of top of skin-plate: metres.	Head on gate: metres.	Height of gate: metres.	Number of decks.
Rosetta barrage . .	+18·80	+11·00	+19·00	7·80 (27′ 5″)	8·00 (26′ 5″)	8
Damietta barrage .	+18·80	+12·00	+19·00	6·80 (22′ 4″)	7·00 (22′ 11½″)	7
Behera regulator . .	+18·90	+10·50	+19·10	8·40 (27′ 7″)	8·60 (28′ 2½″)	9

Note : The following particulars are common to all gates, etc. :

Coping-level	+19·50 metres	(+64 feet 0 inches)
Centres of heel-posts	13·00 ,,	(42 ,, 8 ,,)
Length of each leaf	7·11 ,,	(23 ,, 4 ,,)
Width of each leaf	1·14 ,,	(3 ,, 9 ,,)

tendency for the gates to twist during riveting, throwing the heads of the mitre-posts downstream. Each of these six pairs of gates twisted in the same direction, by amounts ranging from ¾ inch to 3 inches, and it was necessary to correct the twist with hydraulic jacks, when the tie could be drilled and riveted and the strain released. Mild-steel chequer-plate gangways, 5 feet in width, with two three-bar hand-rails, were provided.

The gates are operated by hand capstans working through bevel wheels in pits below the coping-level, gearing with a spur pinion and rack on the operating arm attached near the top of each gate. A holding-brake is fitted to the machinery, and the hand capstan can be disconnected for warping vessels into the lock.

A fourth set of gates was built at the Tewfiki regulator, to replace the old gates, which required renewal after about 50 years' service. This lock has a clear width of 8·50 metres (27 feet 11 inches), and the old gates were of the flat single-skin type familiar on Egyptian canals. As no accurate drawings of them existed, a survey of the lock, the gates, the gate-recesses, etc., had to be made during the canal closure in January

1938. It was found that the old cast-iron hollow quoins had worn away irregularly, and they had to be ground in situ to a slightly increased radius to accommodate the new gates; at a few places steel strips had to be let in to make good excess wear. The new gates had perforce to be of the same size and shape as the old gates, but it was possible to improve certain details and scantlings. Both old and new gates had semicircular heel-posts made from mild-steel plates, but when the new ones were manufactured the plates were pressed over a machined cast-iron block. The shape of the old cast-iron hollow quoins, which could not be renewed in the short time available, precluded the use of green-heart for the heel-posts, but the mitres and clapping-sills were of that timber. The gates are moved by hand-winches operating two chains; the opening chain is connected direct to the gate at about one-third of its height from the bottom and is led over a pulley in the face of the lock-wall up a well to the winch at deck-level; the closing chain is attached to the tail end of the operating beam, which is situated near the top of the gate. A special arrangement of leads for the chains and winches had to be devised for the downstream pair of gates, owing to the new swing-bridge being practically over these gates. Erection of the new gates commenced during the canal closure in January 1939, but was not completed until nearly the end of April, so that navigation in the canal had to be suspended for nearly 3 months.

Penstocks and Stop-Logs.

The three new locks have levelling culverts in the lock-walls, in each of which are three hand-operated penstocks having a clear opening of 1·8 metre to the soffit of the arch by 1 metre wide. The frames and doors are of cast iron fitted with bronze rubbing-strips, and the doors are balanced by cast-iron weights hung in the wells. A separate well and groove is provided at each side of a penstock to take stop-logs in case examination or repairs become necessary.

As the 8-metre spans were too long for the use of single whole timber stop-logs, special flitched beams were designed, consisting of two whole timbers flitched with a 20-inch by 6½-inch by 65-lb. British Standard beam, to the web of which are riveted two 3½-inch by 3½-inch by ½-inch angles for housing the timbers. Stanching at the ends is effected by short vertical timbers. These stop-logs are handled by the caterpillar crane.

Swing-Bridges.

Each of the four locks is spanned by a swing-bridge for road traffic. The loading was a 20-ton ploughing-engine, 12 feet 9 inches long between centres of axles, and 6 feet 3 inches wide between centres of tracks, with a track-width of 1 foot 8 inches, and axle-loads of 12 and 8 tons; over the rest of the deck area the load was 100 lb. per superficial foot. The road-ways are 19 feet wide between curbs, with two 4-foot footpaths. The

bridges rotate on a central pivot and a live ring, and are balanced so that half the swinging load rests on the pivot and half on the live ring. All bridges are of plate-girder construction, and the principal dimensions are given in Table IV.

TABLE IV.

	Rosetta. Damietta. Behera.	Tewfiki.
Radius at nose end	63′ 3″	63′ 3″
Radius at tail end	27′ 10″	30′ 5″
Centres of main girders	14′ 0″	29′ 0″
Diameter of roller path	14′ 0″	19′ 0″
Approximate swinging weight	320 tons	350 tons

The three bridges for Rosetta, Damietta, and Behera are alike in design and details, the main girders being below the roadway with the footpaths cantilevered out. At Tewfiki the undersides of the main girders have to clear the lock gates and their gear; and since the girders have therefore to be raised and are partly above roadway-level, they were placed outside the footpaths. The lower roller-paths were machined on the underside and were bolted direct to carefully fine-axed granite stones, embedded in circular raised masonry pedestals. Folding steel wedges were provided between the top roller-path and the underside of the bridge framework for adjusting the loading, and when the latter had been satisfactorily adjusted the wedges were drilled and bolted. At the nose end, rollers were provided which run on to steel ramps as the bridge nears the end of its travel and lift it sufficiently to prevent the rollers rising off the ramps on account of changes in temperature. Hand-operated wedging gear is fitted at the nose and tail ends. There are two speeds on the operating gear, and the following are the average times of opening and closing :—

Rosetta, Damietta, and Behera.	Opening.	Closing.
Fast gear, 4 men	2 minutes 0 seconds	1 minute 50 seconds
Slow ,, 4 ,,	3 ,, 30 ,,	3 minutes 30 ,,
,, ,, 2 ,,	5 ,, 30 ,,	5 ,, 10 ,,

The Tewfiki bridge, which is heavier and has a roller-path of larger diameter, with more rollers, was considerably slower. Doubtless these speeds will be improved when the gearing has been run in.

The kentledge was all cast in Egypt. The roadways and footways are 4 : 1 fine-granite concrete. Cast-steel chequered curbs are provided on both abutments and also on the nose and tail end of each bridge, with a clearance of 1 inch between the meeting faces.

Valves and Penstocks at the Hydraulic Research Laboratory.

This equipment consists of a number of specially-large valves and penstocks for the various channels. There are three cast-iron bronze-faced valves, each 2 metres in diameter, two for the main inlet to the experimental canal and one for the by-pass inlet direct to the control-chamber, all with short lengths of 2-metre-diameter cast-iron pipe and large heavy bellmouthed inlets. The weight of each, complete with bellmouth, short pipe, hand-worked gearing, and fittings, is 22½ tons. One bronze-faced valve 1·2 metre in diameter is required at the control-chamber for the direct supply of water to the laboratory building through a Venturi meter. Two similar valves, 1 metre in diameter, are installed at the main outlet.

For regulating at the control-chamber three large cast-iron penstocks are necessary, one 3 metres by 3 metres, one 2 metres by 3 metres high, and another 3 metres by 2·75 metres high. These have cast-iron doors, side frames, overhead guides, and cross-framing. Bronze meeting-faces are fitted, and operation is effected by hand-worked worm and screw gearing. Four smaller penstocks, having openings 1 metre and 1·2 metre square, were erected in the measuring-tanks. All of these valves and penstocks were specified to take the full head of water on both sides. The equipment also included several smaller penstocks and valves.

Fittings.

The fittings required in connexion with the barrages, regulators, locks, etc., comprise bollards, fair-leads, cast-iron surface-boxes, hand-railing, galvanized ladders, chequer-plate covers to pits and manholes, ring-bolts in lock-walls, conduits for electric light and power cables, telephone-ducts, water-mains, hydrants, crane-rails for operating-machines, lamp-posts, lamps, etc. No special remarks with regard to these fittings are necessary, except that in view of the rough treatment they receive they had to be of substantial design, whilst the lamp-posts and lamps are also ornamental.

Conclusion.

The cost of the works included in the contract was approximately as follows :—

	£E.
Rosetta barrage	1,050,600
Damietta barrage	823,600
Behera canal and regulator	336,700
Tewfiki regulator reconditioning	64,000
Nagayel regulator and intake	27,000
Hydraulic Research Laboratory	41,900
Road bridges	18,700
Reconditioning of the ancient gateway	3,300
Roads	39,200
	£E2,405,000

This total includes £E386,000 for the mechanical equipment, but does not include any allowances on the Contractors' claims.

The consulting engineers were Messrs. Coode, Wilson, Mitchell, & Vaughan-Lee, the Author being the partner who represented the firm. The resident engineer during the first season was Mohammed Kamel Nabieh, *Bey*, who, on promotion to be an Under Secretary of State, was succeeded by Mahmoud Mohammed Cararah, *Bey*, who remained in charge until the completion of the works. The deputy resident engineer was Mr. G. E. Cheslyn Callow, B.Sc., M. Inst. C.E., and the chief assistant to the resident engineer was Abdul Azim Ismail, *Bey*, M. Inst. C.E. The following Directors of Works were in charge of the three sections of the works: at Rosetta, Mahmoud H. Khater, *Bey*; at Damietta, Ahmad Tewfik Tabouzada, *Bey*: and at Behera, Hassan Mohammad, *Bey*.

Mr. David Myles was in charge of the erection of all the mechanical equipment, whilst Ahmed Said Ibraham was chief quarry inspector and supervised the dressing of the granite at the Aswan quarries.

The Contractors, Messrs. Macdonald, Gibbs & Co. (Engineers), Ltd., were represented at the site by Mr. F. H. Burkitt, C.I.E., O.B.E., with Mr. P. C. Van Hauwaert, B.E., as his personal assistant and Mr. J. E. Tempest as Deputy Agent during the first 18 months. The following were sub-agents in charge of sections: at Rosetta, Mr. G. W. Rowland Owen; at Damietta, Mr. N. Goring; and at Behera, Mr. H. de Broe. Messrs. Ransomes & Rapier, Ltd., who supplied and erected the sluice-gates, operating-machines, etc., were represented by Mr. D. Parsons, and Mr. J. W. Cramer Roberts was agent for Messrs. Head, Wrightson & Co., Ltd., who supplied and erected the lock-gates, swing-bridges, etc.

The Paper is accompanied by six sheets of drawings, from some of which Plates 1 and 2 and the Figures in the text have been prepared, by two photographs, and by forty-two reproductions of the contract drawings.

Discussion.

The Author, in introducing his Paper, showed a series of lantern slides illustrating the works described. He observed that the positions of the two new barrages half-way between the old barrages and the weirs were fixed by the Ministry of Public Works for several reasons, principally because they were downstream of the old barrages, which could be used to shut off the flow of the river during the working season when the foundations could be constructed in comparatively shallow water, thus avoiding excessive pumping; moreover there was no need to interfere to any extent with good agricultural land; both of those factors tended to economy in ultimate cost. The existing weirs were in excellent condition and could be relied upon to relieve the head on the new structures.

Considerable criticism had been expressed because the new barrages were not constructed in one straight line about 1 kilometre upstream of the old barrages, and a committee of six was appointed by the Government to consider that matter. The alternative proposal was examined from every point of view, and the Committee reported unanimously in favour of the downstream site. Incidentally, the upstream proposal would have entailed the construction of the barrages in the pool formed by the old barrages, and have necessitated a higher head of at least 3 metres on the temporary dams, thus entailing much heavier pumping costs during construction. The Government experimental farm between the two branches of the river would have been cut up by new canals, roadways, and contractors' workyards, whilst the new Behera canal diversion would have been much longer and would probably have entailed the expropriation of a large village: there was, moreover, a scoured hole about 50 feet in depth on the proposed site for the Damietta barrage which would have complicated matters somewhat.

The existing old barrages were magnificent pieces of work, and with their minarets and towers formed a fine sight, but their foundations and underwater work were not all that could be desired. The task of remodelling them on the lines of the Assiut barrage would, in the Author's opinion, have been a hazardous and costly undertaking, and not worth the risk when for practically the same expenditure new structures of modern design with modern sluice-gates could be provided. The construction of new barrages was fully justified, seeing that the whole of the irrigation of the Egyptian Delta depended entirely upon those barrages. The old barrages were to remain, and would be used for light vehicular traffic, whilst the old sluice-gates were capable of being regulated on in case of emergency.

To illustrate the care necessary for regulation on the old barrages, the Government used the "4-to-1" rule, which meant that since the barrages were strengthened to withstand the maximum upstream level of + 15·70, or 3 metres head on the structures, no increase might be made in the upstream level without an increase in the downstream level of four times the upstream increase. The Author understood that that rule was adhered to rigidly, and that the only attempt ever made to go beyond it was unsatisfactory, and the rule was therefore not departed from. That decree caused considerable waste of water on a falling flood when high levels were necessary in the three main canals serving the Delta. From the abovementioned and other facts it was recognized that the old barrages were working under their maximum capacity, and it was a very wise decision of the Egyptian Government to provide new works of a reliable and modern design.

The Author wished to pay tribute to the great help afforded by the Ministry of Public Works, and more particularly by H. E. Hussein Sirry, *Pasha*, who for many years was Under-Secretary of State, later Minister of Public Works, and was now Prime Minister of Egypt. He had been the moving spirit in connexion with the Gebel Aulia dam, the remodelling of the Assiut barrage, and the Mohammad Aly barrages. Considerable opposition had developed to all of those three schemes, and it was due to Hussein Sirry, *Pasha*, that that opposition had been overcome and the works duly carried out. He was an engineer by profession, and a worthy successor to his father, Sir Ismail Sirry, *Pasha*, K.C.M.G., who was Minister of Public Works for many years.

Mr. W. J. E. Binnie, Past-President, observed that the Paper covered a very wide field and described in great detail the construction of the works. There were several points of scientific interest on which he would like to touch. The first was the question of the hydraulic gradient through the sand, that was, the theoretical gradient, meaning the distance of the shortest path which the water would have to travel in passing under the structure, divided by the difference in level above and below the sluices. On p. 248 it was stated that that gradient was 1 in 24—presumably, as measured over the entire length of the floor. The actual impermeable floor—the concrete portion—was continued both upstream and downstream by block pitching. The Author had given an explanation in the note attached to *Fig. 5* (p. 243), where it was stated that the joints between blocks and interstices in the rubble became filled solid with silt after the first flood, the water no longer having free access. Assuming, however, that that did not occur, the gradient would be about 1 in 18 over the length of the impermeable concrete. That seemed to be a very conservative gradient, but it would depend, of course, upon the nature of the underlying material. Mr. Binnie would like to know whether that material was homogeneous, that is, whether it was sand of more or less equal grain over the whole of the foundation, or whether it was variable; if it were regular,

perhaps the Author could give some idea of the grain size. Had a similar gradient been adopted on other barrages on the Nile?

The whole history of those two barrages provided an illustration of the necessity of providing a long enough apron. The only similar case with which Mr. Binnie's firm had had to deal was the Pontian reservoir. There were two embankments: one was across the valley where the river was now flowing, and the other was about ½ mile in length across what had been a swamp before it was drained, and which was overlying an older river channel. The depth to get down to the rock was very considerable, and owing to the nature of the material, which was waterlogged—being disintegrated granite, sands, and clays—it was impracticable to take the foundations down to any great depth without prohibitive expenditure. The consequence was that for the cut-off wall, open excavation was carried as far as possible—from 15 to 20 feet below the surface—without serious difficulties from irruption of water being encountered, and then piles were driven, the total depth from the surface being about 60 feet. The piles were similar in character to those described in the Paper. There was an inner wall at the toe of the embankment, and the outer portion of the bank was laid on a blanket of broken stone, the material forming the bank being only slightly permeable. The hydraulic gradient, taking the height of the water in the reservoir with the length of the shortest course the water would have to travel, was only 1 in 7. The material, as revealed by boreholes, was very lenticular in character, the record of one borehole bearing hardly any resemblance to that of another. Mr. Binnie had felt rather doubtful whether the water had really been given a long enough path to travel, but it turned out to be sufficient, as there was no leakage coming from underneath. That formed an illustration at one particular place, but every individual site had to be studied before an idea of what to do could be arrived at.

With regard to the granite deflecting weir, illustrated in *Fig. 5*, it was not represented as cut into lengths, and Mr. Binnie assumed that it was a solid weir right across; and he would like to know whether it had been adopted as a result of model-experiments and had proved successful. A good laboratory had existed at the barrage for many years, where hydraulic model-tests could be carried out. Mr. Binnie had visited it in 1928 with Dr. Gruner, of Switzerland, and they were both remarkably struck by the work carried on there. The results, however, were published only by the Egyptian Government, and had not received the wide publicity in the engineering profession which they deserved. It was an exceptional position on account of the quantity of water which could be diverted from above to below the barrage-lock, and particularly valuable results had been obtained from experiments on submerged weirs. The Author had referred to the Rosetta barrage, where sand was substituted for mud in the foundations. A thick layer of mud was discovered, and had proved perfectly satisfactory.

Sir Bernard Darley considered that it was very fortunate that whenever a large and important irrigation work was constructed, either in Egypt or the Sudan, some engineer like the Author was prepared to write an excellent Paper for The Institution, so that the world was given information about the design and construction of such works. It was a great pity that in India that practice had not always been followed. During the past 15 years seven barrages had been completed in Northern India, but he did not think that their descriptions had been presented to The Institution as they should have been. Five of those barrages were in the Punjab, one in the United Provinces, and one in Sind. He would like to mention points where the design of those barrages differed from the description given in the Paper. The first was in connexion with the floor. A very massive floor had been provided in the Mohammad Aly barrages. In India it was usual upstream to put in a concrete skin, which was seldom more than $2\frac{1}{2}$–3 feet thick. There was a downward pressure of water which counteracted any upward pressure underneath the floor. Downstream, the foundations were usually stepped up, because the hydraulic upward pressure was decreasing and therefore a smaller thickness of concrete was needed. He believed that the Sukkur barrage, in Sind, was the only one that had a floor approximating to the Egyptian design. A very novel design in the Punjab had been completed in 1939, in which the whole barrage was built on the top of a flat, thin-skinned, highly-reinforced concrete floor, weighted by means of piers downstream. That barrage had thirty-seven bays of 60 feet and fourteen under-sluices, each of which was of 30-foot span. It had been a very cheap design because the expense lay largely in the pumping and the foundation work. That design had been accepted after an intensive study of pressures under existing weirs and of model-experiments, which had formed the subject of a Paper published by the Central Board of Irrigation[1]. The old-time hydraulic gradient theory had been more or less given up; it did not hold when sheet-piling was put in. The flow of water had been studied under weirs in those model-experiments, and results demonstrated that the water travelled in a manner different from what had been previously thought.

The second point of difference was that in Egypt, as a rule, very narrow openings were provided. Those described in the Paper were 8 metres. In India the openings were larger. One reason was that often heavy trees floated down the stream; but the principal reason was that it had been found that a large number of bays necessitated a large number of piers, entailing an additional length of flooring, which was the expensive part of the barrage. Therefore the width of the bays was usually fixed at between 50 feet and 60 feet, as being most economical; in fact, six of the seven barrages completed during the past 15 years in Northern India had 60-foot

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[1] A. N. Khosla, N. K. Bose, and E. M. Taylor, "Design of Weirs on Permeable Foundations." Publication No. 12, Central Board of Irrigation, India. Simla, 1936.

spans. He was not sure why such very small spans were adopted in Egypt.

Of course, with very wide spans it was necessary to have very massive gates. In India, the gates were of the Stoney type, and free rollers were adopted instead of fixed rollers, which sometimes gave trouble owing to silt and floating debris. He noticed, from the Paper, that special pains had been taken to avoid that trouble.

In barrages in Northern India—that was, in the Punjab—the gates were usually operated from a platform above resting on steel girders, and the roadway was also carried on steel girders. The Sukkur barrage, however, had stone arches similar to those described in the Paper, because stone happened to be close to the site. The gates were always raised by means of steel ropes passing over drums situated over each end of the gate. These drums were on a fixed spindle, and very minute regulation could be obtained in that way.

Perhaps the most striking difference between Indian and Egyptian practice was in regard to the siting of the canal-heads. Silt was the bugbear of the irrigation engineer, and everything possible was done to exclude it from the canals. Therefore the canal-head was always placed immediately adjacent to the barrage; water was drawn into the canal-head over a raised masonry crest, and thus all the very heavy and coarse river-silt was kept out of the canal. Under-sluices were always provided which formed a continuation of the barrage and were usually divided from it by a wall running up in front of the canal-head and forming a kind of pocket through which only the water entering the canal could be passed. The water was thus drawn off from a still pond without turbulence. The under-sluices were, however, opened periodically to clear the pocket of accumulations of silt.

From the Paper, and also from other Papers which had been presented to The Institution, it appeared that in Egypt the canal-heads were usually placed some distance upstream away from the barrage—about a mile in the case of the Rosetta barrage—and the regulator for that canal-head was situated about 1,000 feet down from the river-bank, forming a considerable pocket. In India during the height of the flood-season that pocket would become filled with silt within a week or 10 days, and when the floods fell there would be considerable difficulty in getting water into the canal, and also navigation would not be easy. On p. 250 of the Paper model-experiments were mentioned, but Sir Bernard Darley was sure that irrigation engineers would be glad to know whether silt trouble did actually occur in that pocket or in the canal.

Mr. Binnie had referred to the laboratory and to the good work done there. In Lahore also there was a very fine laboratory, where excellent work was done which was not widely published. It would be a great thing if both laboratories would present Papers to The Institution periodically so that the outside world could learn what was being done, and it would be a

matter of congratulation if Indian engineers could meet Egyptian engineers from time to time and exchange ideas. Irrigation was different in every country, but the laws of nature remained the same.

Dr. W. L. Lowe-Brown said that he would confine his remarks to the design of the barrage floors. In the light of his own experience in the operation of the Assiut barrage[1], he was glad to see that the downstream apron gave efficient protection to the river-bed for a distance of 67 metres below the sluice-gates. The upstream apron of the Mohammad Aly barrages was much stronger than the original apron at Assiut[2], where the solid concrete extended only about 7·5 metres upstream of the sluice-gates, but was followed by 14 metres of clay puddle protected by a covering of 1 metre of stone pitching, whilst beyond that was a further 6 metres of stone pitching: in contrast, in the Mohammad Aly barrages the concrete floors extended 21 metres upstream of the gates, with an extension of 10 metres of heavy concrete blocks. The old floor at Assiut had never given any trouble, and according to Mr. J. E. Bostock's Paper on the remodelling of that barrage[3] "the original apron upstream of the solid barrage floor, composed of hand-packed rubble on a layer of clay, was found to be undisturbed and in good condition." That was a good tribute after nearly 40 years in service. In the circumstances Dr. Lowe-Brown thought that it would add to the value of the Paper if the Author would explain why he had made the upstream aprons of the new barrages so much stronger than the old apron at Assiut, as they could never be subject to impact or to severe scour.

With regard to the hydraulic gradient of 1 in 24 which the Author had used in the design of all the foundations, it would perhaps be advisable to define what exactly was meant by that gradient, because in Mr. A. R. Ellison's Paper on the Nag Hammadi barrage[4], it was stated that that work was designed to give a hydraulic gradient of 1 in 18; yet it would appear from a comparison of the two designs that there was not much difference in their hydraulic gradients. Perhaps the difference lay in the manner in which the hydraulic gradients had been measured. The method used by the Author was that described in a book[5] by Mr. W. G. Bligh. According to that method it was assumed, in measuring the length of the path of the leakage under the foundation, that it followed the outline of

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[1] Discussion on "The Causes and Prevention of Bed Erosion." Minutes of Proceedings Inst. C.E., vol. 235 (1932–33, Part 1), p. 227.

[2] G. H. Stephens, "The Barrage across the Nile at Asyût." Minutes of Proceedings Inst. C.E., vol. 152 (1903–4, Part IV), p. 26.

[3] "Remodelling of the Assiut Barrage, Egypt." Journal Inst. C.E., vol. 14 (1939–40), p. 301 (June 1940).

[4] "The Nag Hammadi Barrage, Upper Egypt." Minutes of Proceedings Inst. C.E., vol. 232 (1930–31, Part 2), p. 340.

[5] "The Practical Design of Irrigation Works." Constable & Company, Limited, London, 1927.

the masonry, the sheet-piles, and the other cut-offs. That length had been measured on the various barrages across the Nile, and the maximum head on each and the corresponding hydraulic gradient were given in Table V.

TABLE V.

Name of barrage.	Head: metres.	Length of line of creep (Bligh): metres.	Hydraulic gradient.	Revised length of line of creep: metres.	Revised hydraulic gradient.
Original Assiut	2·5	57·5	23·0	40·5	16·1
Nag Hammadi, in flood	4·0	89·25	22·3	69·25	17·3
Nag Hammadi, at low Nile	4·5	89·25	20·0	69·25	15·4
New Assiut	4·2	103·0	24·5	73·0†	17·3
Rosetta	3·8	98·8	25·3	80·0	21·1
Damietta	3·8	98·8	25·3	80·0	21·1
Behera regulator	3·5	85·0	24·3	54·0	15·4

† Including grouted Rotinoff reinforced-concrete interlocking sheet-piling.

The essential condition for hydraulic gradient was, of course, that it must be flat enough to prevent "piping," that was, dislocation of soil-particles, beneath the structure. However flat the hydraulic gradient there would always be a flow of water under the structure; and Mr. A. B. Buckley, M. Inst. C.E.[1], had made an interesting calculation of the quantity of water passing under the Nag Hammadi barrage.

The mathematical treatment of the flow of water under foundations of that nature, used in the study of soil mechanics, indicated that the water followed a series of stream-lines ranging from the line of creep to much straighter lines lower down. The ordinary soil-mechanics curve was based upon the assumption that all the leakage took place through the pores of the subsoil, that that subsoil was homogeneous, and presumably that there was no leakage between the concrete floor and the underlying material, but experience seemed to show that the line of creep used by Mr. Bligh was the important one, along which most of the leakage flowed. Before it could be assumed that the leakage would follow that outline there must obviously be some limitation of the distance apart of the lines of sheet-piling, for if they were very close together the water would jump across from line to line instead. Mr. Bligh had assumed that, provided the distance between two lines of piles was not less than twice the depth of the piles below the floor, the percolation might be assumed to follow the outline of the piles and the floor. In a discussion on that subject at a Punjab Engineering Congress in 1929–30[2], Mr. Gerald Lacey, M. Inst. C.E., had pointed out that the implication of that theory was that

[1] "The Nag Hammadi Barrage, Upper Egypt." Minutes of Proceedings Inst. C.E., vol. 232 (1930–31, Part 2), p. 368.

[2] Proceedings of the Punjab Engineering Congress, vol. 18 (1930), p. 212*d*.

the loss of head between piles and sand, or between masonry and sand, was only half that between sand and sand. One point related to that which had often been overlooked was, that if the measured hydraulic gradient through a sandy embankment were 1 in $7\frac{1}{2}$, then the same material underlying a weir would require a hydraulic gradient of 1 in 15.

Dr. Lowe-Brown had always thought that it was over-optimistic to assume that lines of sheet-piling could form a complete cut-off for percolating water, because if any leakage occurred, local "piping" might result, which would eventually bypass the lines of sheet-piling; of course, that did not apply to double lines of sheet-piling filled with concrete. From the remarks of Sir Bernard Darley, he gathered that that view had now been accepted in India. On that revised basis, omitting single lines of sheet-piling in measuring the length, the hydraulic gradients of the Egyptian barrages had been recalculated, and were also given in Table V. It would be seen that even on that more conservative basis the hydraulic gradient was always flatter than the value of 1 in 15 used in Indian practice.

Another assumption made by Bligh's theory was that the loss of head followed a straight-line law throughout the leakage-path. It had, however, been felt for some time that, although that theory was extensively used in India and elsewhere as a convenient basis for design, it did not rest upon a satisfactory large-scale experimental basis. Many observations on the loss of head by percolating water had been made on actual irrigation works in India, and all pointed to the conclusion that the loss of head did not follow a straight line, but was slower at the top of the gradient and increased gradually towards the bottom, giving a curve rather like the shape of the cone of depression in the ground-water table caused by pumping. The result was that the uplift pressure at intermediate points might be considerably higher than that indicated by the straight-line theory, and consequently, many works designed on the Bligh theory might have only their factor of safety standing between them and damage by uplift.

Mr. Richard Stokes, M.P., remarked that the slides exhibited by the Author illustrated the magnitude of the scheme, and enabled the considerable thought, work, and ingenuity required for its successful execution to be realized. Mr. Stokes's firm had had the honour and pleasure of providing all the operating gear and gates for the barrage, and the work had concluded a 46-years association with the Egyptian Government, beginning with the large Stoney sluice for the old Behera canal.

One or two technical points about the grooves and gates might be of interest. In the test described on p. 260, the load was applied to a groove through a short block 5 inches wide, to represent as nearly as possible the worst effect of a load imposed by a sluice-roller. As the roller load was of the order of 14 tons, and the casting cracked at 175 tons and broke at 190 tons, it was obvious that a very high factor of safety was provided,

and it said much for the type of cast iron of which the grooves were made. The casting broke along the lines of the holes for the downstream fixing-bolts. In service the casting would actually carry a greater load before fracture than was indicated by the test, because in service it received support from the fixing-bolts; no attempt was made during the test to reproduce that support, as its amount was an indeterminate quantity. The lower gate had its girders on the downstream side of the skinplate, in order to diminish the quantity of silt-deposit should the gate remain down for any length of time. A section of the gate had been tested at Ipswich: it was loaded with 80 tons distributed over the skin, and the vertical deflexion was about $\frac{2\frac{1}{2}}{32}$ inch. The section was unsymmetrical, but the transverse deflexion was almost negligible. The normal load on that part of the gate was 20 tons.

The operating machines were jointly designed by the Author and by Messrs. Ransomes and Rapier, Ltd., the greater credit being due to the former. Mr. Stokes wished to emphasize the great accuracy achieved in the construction of the gates by the use of jigs throughout their manufacture in the works. That enabled them to be put together with the greatest facility, and ensured that when the material arrived at the site everything was interchangeable, so that the person responsible for their assembly on the spot had very little trouble. In connexion with the assembly, a difficulty with which his firm had had to contend was that they were required to work in so many places at the same time. He wished to add a personal word of appreciation of the staff, because it was owing to the foresight of the supervisor in charge and those under him that the work was completed in such good time and so satisfactorily, at a comparatively low cost.

He would also like to congratulate the Author upon the magnificence of the masonry work on the barrage. He agreed with the Author's tribute to H. E. Hussein Sirry *Pasha*, the Prime Minister; it was largely due to his work and to that of his late father that Egypt had gone ahead so fast with irrigation. Hussein Sirry *Pasha*, was a great friend of Britain.

The temper of the present day appeared to aim at destroying such works, and the only political expression which Mr. Stokes would permit himself was that it did seem distressing that there were not more engineers in direct, active, and close contact with, and participating in, the government of Great Britain.

⁂ **Mr. J. E. Bostock**, who had been fortunate enough to pay frequent visits to the works, considered that the engineers, and the Author in particular, had used their intimate knowledge of granite work to produce the right amount of ornamentation on structures embodying strength with a pleasing aspect. The statement, in *Fig. 5* (p. 243), that the joints between the blocks were filled with silt during one flood season,

⁂ This contribution, and also the following, were submitted in writing.

had been borne out at Assiut, where it had also been observed that in cases where work of a previous season was exposed and subjected to a substantial head, the silt was forced up through some of the joints by rising spring-water. Very little of the underlying lighter coloured sand, however, was washed upwards by the unnatural head. That tended to show that, in normal working, it was doubtful whether any of the sand underlying the apron blocks would be disturbed. Perhaps the Author could outline the functions of the Hydraulic Research Laboratory, and state whether he knew of the existence of any similar installation in the United Kingdom.

With regard to the expansion joints, as designed in the structures, was the Author able to state whether any of the cracks usually found in other similar structures had developed in the new work? Such cracks were inclined to cause misgivings to strangers to that class of work, where expansion and contraction (breathing) was bound to occur. After watching such cracks for a time, anxiety on the subject disappeared, provided that the structures were stable and in good condition.

Mr. Bostock had sometimes been asked why the upstream aprons of recent barrages and dams were so wide, in view of the fact that the original rubble and clay aprons at Assiut were found in perfect condition, and that normally the apron was covered with sand to within a short distance of the piers; and he had replied that no one could say how much, if any, sand covered the aprons during the flood. Moreover, the abnormal had to be provided for, such as would happen if a heavily-laden vessel of any sort sank near the structure (as frequently happened). Such obstruction might rapidly cause a 5–10-metre scour which might endanger the structure in the absence of an efficient apron. The length was also required to obtain the necessary hydraulic gradient. The Author might be able to furnish further cogent reasons.

Mr. John Palmer considered that the lantern-slides exhibited by the Author demonstrated that the Egyptian Government had got their money's worth, and that the barrages presented both a monumental and an artistic appearance.

The sum of £2,500,000 must have been a fairly large item in the Egyptian Budget, and he would be interested to hear whether the Author had been asked to prepare any kind of balance-sheet to show, perhaps, that the increase in revenue that might be expected from better water-distribution in the Delta would make the job a paying one; interest and sinking fund on capital would presumably amount to about £110,000 or £120,000 per annum. The rough "all-in" cost of the two big barrages themselves was slightly more than £8 per square foot, taking the overall lengths and only the pier-widths: obviously if any greater width were taken to allow for the very much wider floor, the cost per square foot would be reduced to £4 or less, which was often used as an approximate estimate for bridging. Further, of course, the sum of £8 per square foot included the provision of a 250-foot lock. The cost, therefore, did not seem to be

at all heavy, although clearly the monumental appearance was not achieved for nothing. It would be interesting if the Author would state whether he had calculated how much could have been saved by adopting, say, concrete structures.

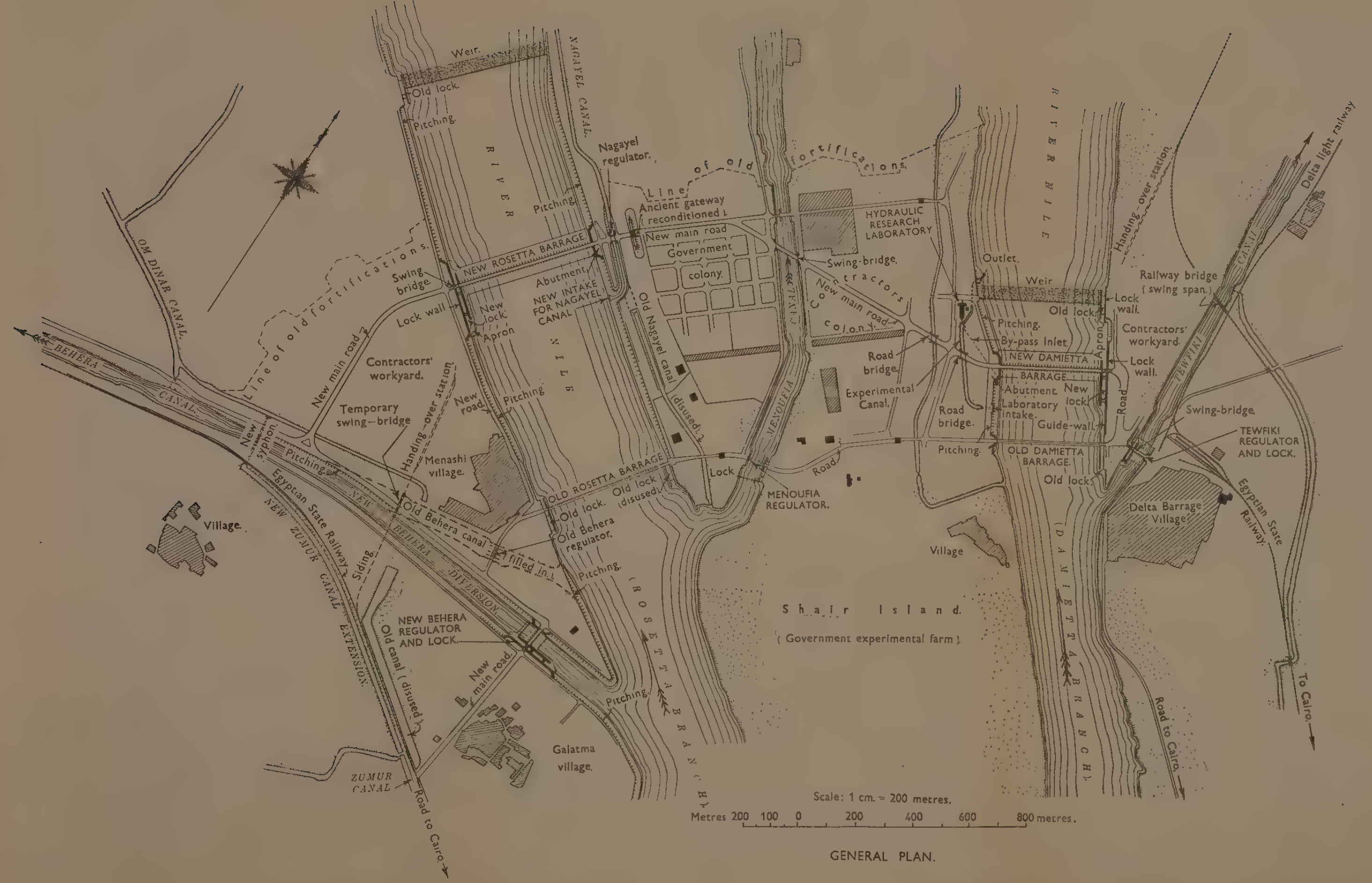
The Author, in reply, observed that the hydraulic gradient appeared to have been the point upon which most information was required. On the two main works, the Damietta and Rosetta barrages, the gradient was fixed at 1 in 24, the measurement of the water-creep being taken along the underside of the solid impermeable floor, and up and down the cut-offs and steel piling. That might seem to some engineers to be a rather extravagant allowance, but it had to be remembered that the existing weirs downstream of the barrages were taken into account for relieving the head on the new structures. Those weirs were in excellent condition, but should an accident occur and damage be caused to a weir, there would still be a hydraulic gradient of 1 in 13 to be relied upon until repairs could be effected. That was the basis of the calculations, and it was a case of striking a happy medium. The gradient of 1 in 24 was also adopted for the worse condition at the Behera canal regulator, when there was a head of 3·50 metres during the canal closure period. In all cases the blockwork aprons were ignored. Mr. Binnie had raised the question of the homogeneity of the sandy material forming the foundations. The material varied in different locations and, moreover, it might vary after each flood, depending upon the various sizes of the grains of sand carried down the river. No true and concise analysis of the material could be given, except to state that it was fine, small-grained sand mixed with a small proportion of silty mud. The design for the granite deflecting-weirs on the downstream toes was arrived at after experiments had been carried out on models and it would be noticed that, whereas the weirs at the barrages were 50 centimetres above surface-level, the Tewfiki regulator required a weir 70 centimetres high to obtain the best results. The upper deflecting-weir at the Tewfiki regulator (*Fig. 2*, p. 242) was added at the last moment during construction, as further experiments had shown that that would be beneficial.

Sir Bernard Darley's remarks concerning the publication of the results of experiments carried out in laboratories were much appreciated, and were concurred in by the Author, who also considered that such valuable information should be available for the use of the engineering profession from time to time. It was early yet to say whether any considerable siltation would occur in the length of canal upstream of the Behera regulator, but the model-experiments did not give cause to anticipate any serious trouble from that source. The entrance was designed to give a clear, straight run for the current towards the regulator, as free as possible from eddies.

The answer to Dr. Lowe-Brown's questions as to the design of the upstream blockwork apron, and why rubble and clay were not used, as in

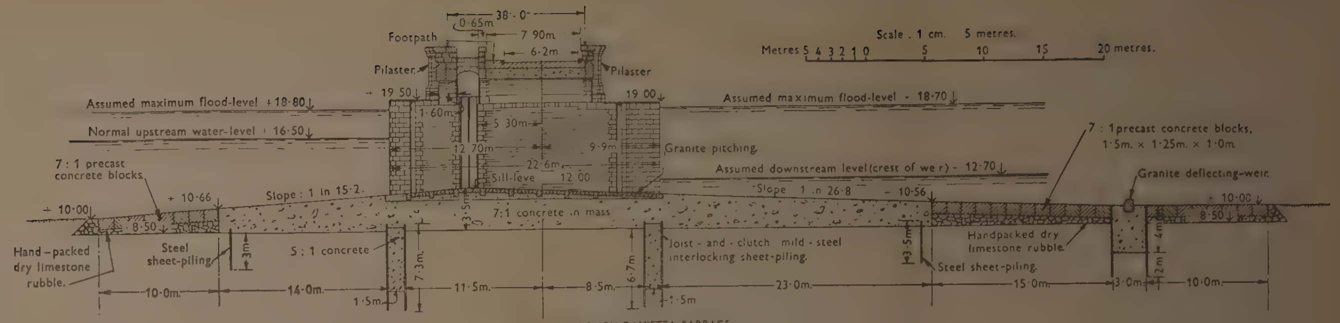
THE MOHAMMAD ALY BARRAGES, EGYPT.

FIG: 1.



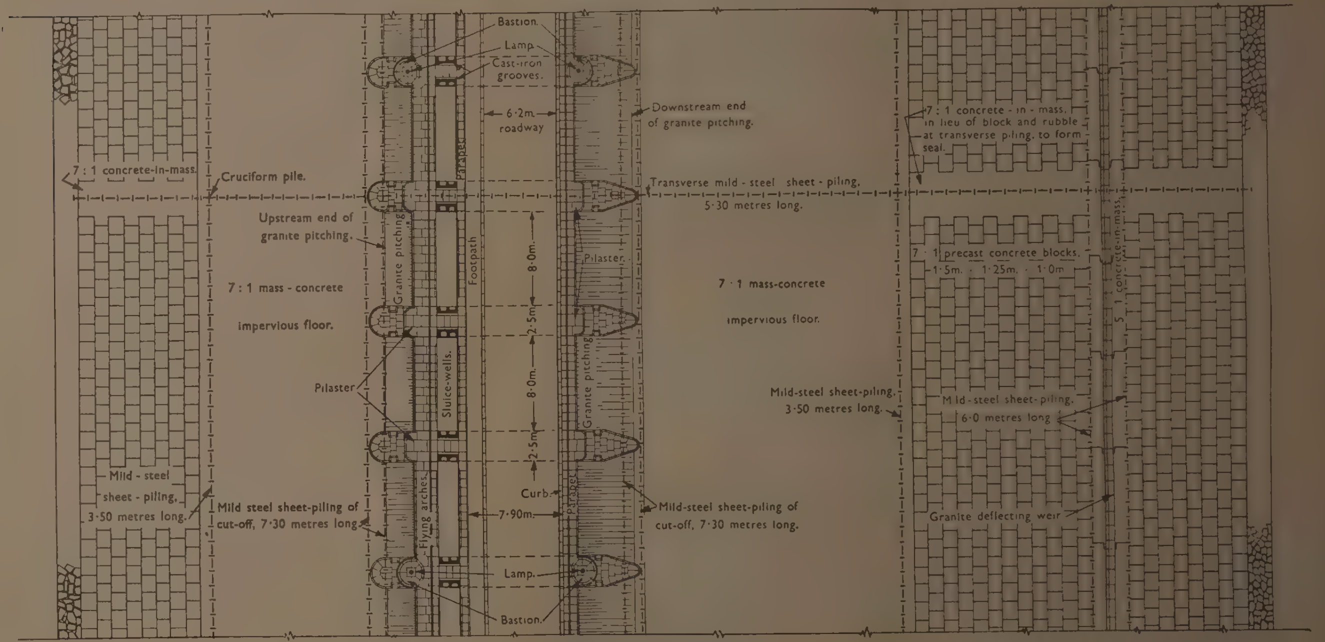
GENERAL PLAN.

FIG: 3.



SECTION THROUGH DAMIETTA BARRAGE

FIG: 4.

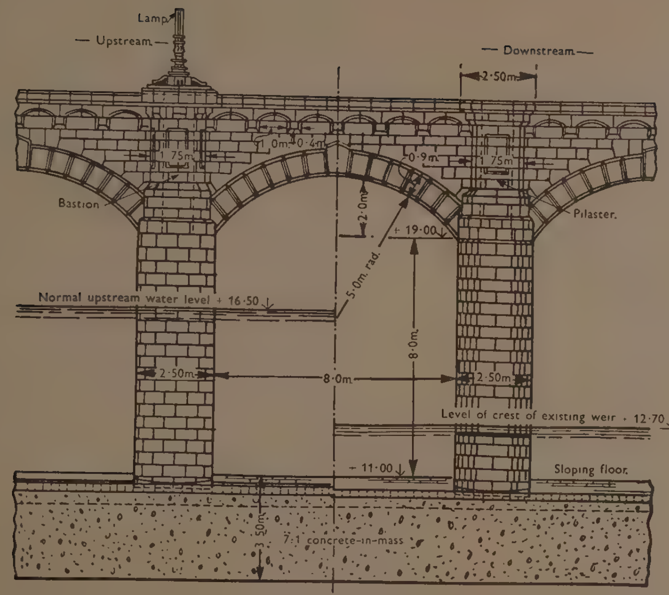


PART TYPICAL PLAN OF BARRAGES.
DAMIETTA BARRAGE.

A. G. VAUGHAN-LEE.

THE MOHAMMAD ALY BARRAGES, EGYPT.

FIG: 6.



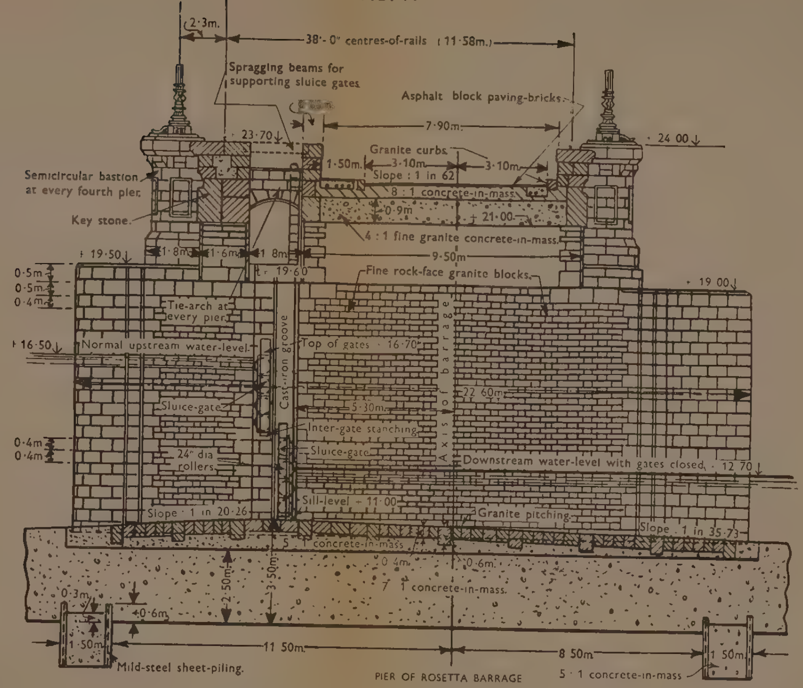
PART ELEVATION OF ROSETTA BARRAGE

Scale 1 cm = 2 metres

Centimetres 200 100 0 2 4 6 8 10 metres.

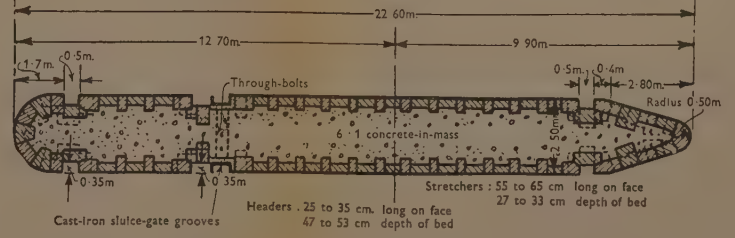
Figs 6, 7, and 8 are also typical of the Damietta barrage and the Behera regulator.

FIG: 7.



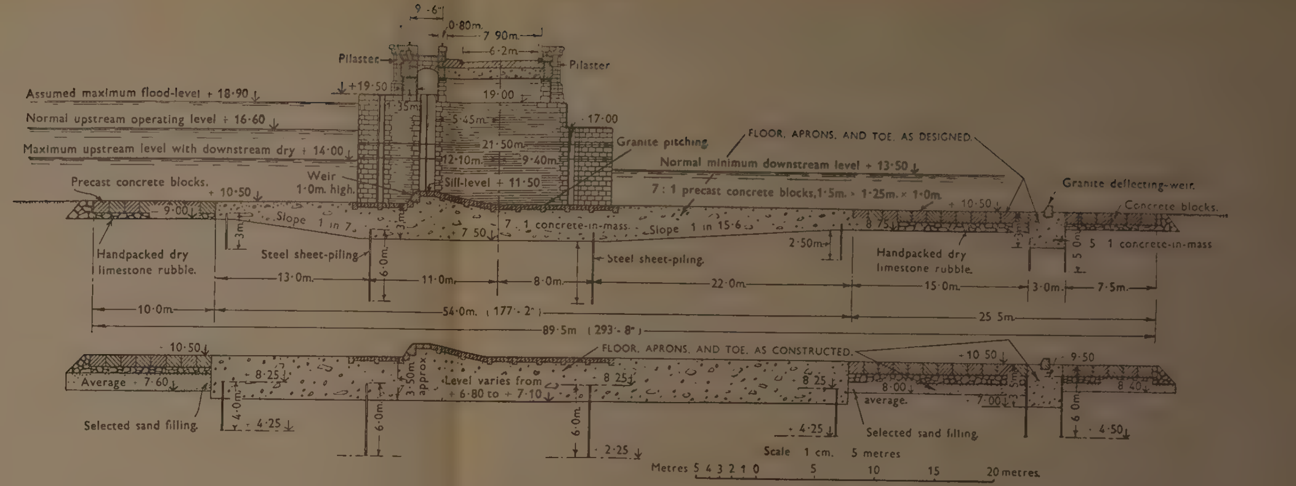
PIER OF ROSETTA BARRAGE

FIG: 8.



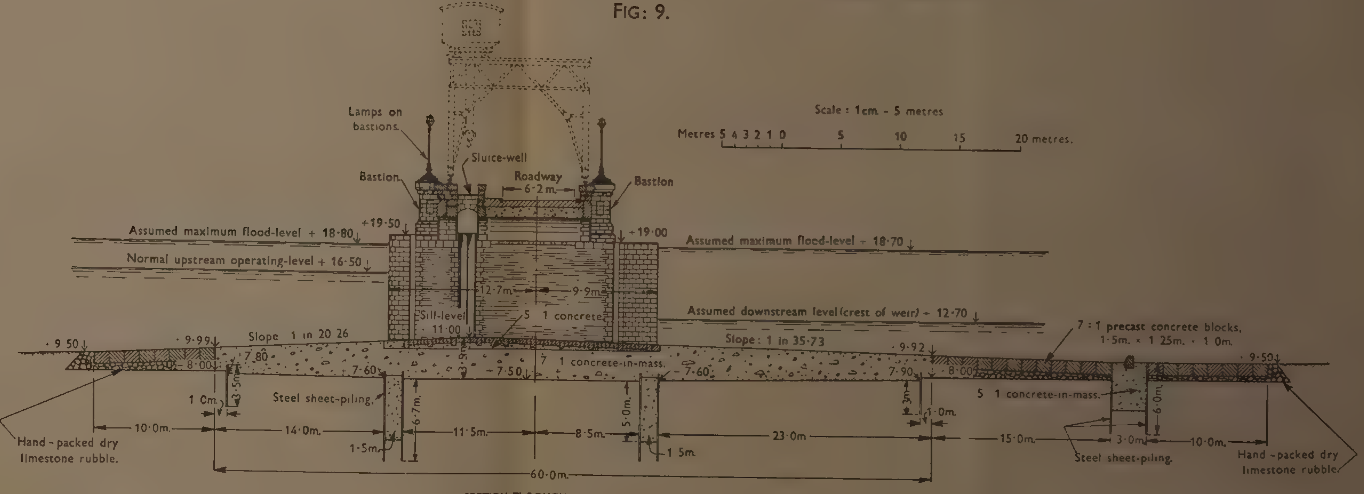
SECTIONAL PLAN OF PIER

FIG: 10.



BEHERA REGULATOR

FIG: 9.



SECTION THROUGH ROSETTA BARRAGE.

ROSETTA BARRAGE

WILLIAM CLOWES & SONS, LIMITED: LONDON.

A. G. VAUGHAN-LEE

the original Assiut barrage design, was as follows. It was found at Assiut that the upstream rubble apron was displaced by flood action from time to time, and had to be replenished, although the underlying clay was found to be generally intact. As much as 6,000 cubic metres of rubble had been deposited upstream for replenishment purposes, and it was therefore considered advisable to adopt a more permanent design, as at Nag Hammadi and in the remodelled Assiut design; and as Mr. Bostock had stated, precautions had to be taken to prevent the occurrence of deep scour due to sunken craft or other obstacles immediately upstream of the permanent work. The Nag Hammadi barrage was designed for a hydraulic gradient of 1 in 18, but mild-steel sheet-piling was added to the eastern ninety vents during construction at the upstream and downstream terminations of the impermeable floor, in order to confine the area of the foundations for grouting purposes. That might have led to the apparent discrepancy alluded to by Dr. Lowe-Brown.

A telegram received recently from the Ministry of Public Works had indicated that slight cracks had appeared in the concrete of the intrados of some of the arches of the vents; but the Author was informed that they were of no consequence, and as Mr. Bostock had observed, they gave no cause for anxiety. The Author was not aware of any establishment in Great Britain that would fulfil functions similar to those of the proposed Hydraulic Laboratory at the barrages, unless it were at Teddington. For some time there had been in existence at the barrages a long tank with a mechanically-operated travelling carriage, which was used for adjusting and regulating the current-meters used in recording the discharges of the river and the canals.

There were approximately 5,000,000 acres of cultivated land—or would be when further areas in the north of the Delta had been reclaimed, irrigated, and drained—and it would be a fairer calculation to compare the cost of the work with the acreage. That would work out at about 10 shillings per acre on the contract cost. The construction of the superstructure of the barrages in concrete was not considered, as suggested by Mr. John Palmer, owing to the Government requiring stone facing.

Paper No. 5183.

"The Uhl River Hydro-Electric Project."

By HERBERT PERCIVAL THOMAS, C.I.E., B.Sc., M. Inst. C.E.

(*Ordered by the Council to be published with written discussion*)[1].

IN October, 1921, a survey of the hydro-electric possibilities of the Punjab was commenced by Major R. N. Aylward, D.S.O., M.C., under the supervision of the late Colonel B. C. Battye, D.S.O., M.C., Assoc. Inst. C.E., on the instructions of the Punjab Government, and attention was called to the possibility of developing power from the Uhl river. Part of the Uhl basin is shown in *Fig. 1.*

The first project put forward was for the development of 118,400 kilowatts, at an estimated gross capital cost of 121,000,000 rupees. The scheme was to be developed in three stages. The first stage was to comprise head works in the Uhl river valley, a tunnel through the range between the Uhl river and Joginder Nagar, and a power house at Joginder Nagar. The second stage consisted of the addition of an arch storage dam, 220 feet high, with a crest 612 feet long, in a rock gorge in the Uhl valley, creating a storage of 21,500 acre-feet. The third stage was to utilize the tail water from the Joginder Nagar plant through a drop of 1,200 feet, made available by leading the water in a 4-mile flume round a spur below the power house which terminates above a bend of the Neri Khad.

The present development follows the lines of the first stage of the original project. The waters of the Uhl river and its tributary, the Lambadag, are impounded by weirs above the junction of the two rivers, and are led off through decantation chambers by flumes to the tunnel. The tunnel, 3 miles in length, pierces the range dividing the Uhl valley from that of the Neri Khad, a small stream which finds its way into the Beas river, and the water passes on down through penstock pipes to the power house 2,000 feet below the intake on the Uhl river. The chief point of interest in regard to the head works is the equipment for ensuring that the water reaching the turbine jets is free from sand and gravel. The Uhl weir is equipped, in its mid-stream section, with a falling gate which subsides into the river bed and is capable of supporting 15-ton boulders as they are rolled down in the monsoon floods. The water taken in at the off-take above the impounding weirs is passed through decantation chambers, fitted with

[1] Correspondence on this Paper can be accepted until the 15th June, 1941, and will be published in the Institution Journal for October 1941.—SEC. INST. C.E.

"venetian-blind" concrete slabs in the floors of compartments of the "hopper-bottom" type, through which the deposited silt is scoured into

Fig. 1.

THE SITE OF THE WORKS IN THE UHL BASIN.

scour ducts, and so returned to the river below the weirs. The decantation is effected by enlarging the cross-sectional area of the chambers till the speed of flow is reduced to 1 foot per second at full demand. This has been found most successful since no abrasive particles of sand or silt have

reached the nozzles ; the wear on the needles and buckets after 5 years is hardly discernible.

The 3-mile tunnel is 9 feet 3 inches in diameter inside the lining, and in various places necessitated special methods of driving. The Himalayan mountains are amongst the newest known and are composed very largely of rocks, twisted and shattered by the working of the earth's crust which has caused their evolution, so that nowhere, throughout its entire length, did the tunnel penetrate rock of such a soundness that it could be left unlined ; in many places progress was only made possible by installing steel sets made from rolled-steel joists at 4-foot centres, supporting a sheathing of reinforced-concrete slabs. Those sets and the concrete slabs were embedded in the concrete lining of the completed tunnel. The tunnel was extremely wet owing to the infiltration of water from the seams, and, in places, jets of water spouting from the walls or roof, when confined, registered pressures ranging from 60 to 80 lb. per square inch. A detailed description of the methods used in driving and lining this tunnel is given in a Paper [1] presented before the Punjab Engineering Congress in 1932.

From where the main tunnel ends, two 6-foot-diameter pipes, surrounded by 2 feet of concrete, carry the water 1,100 feet to emerge on the hillside at the valve house. Building the surge tank at the junction of these pipes with the tunnel constituted a difficult problem. When the second stage, including the 220-foot dam, is built the surge-shaft chamber will be subjected to a static pressure due to a head of 300 feet ; the rock at this point is so shattered that even the 6-foot steel pipes had to be protected throughout their length of 1,100 feet by a 2-foot casing of concrete. Loss of water could not be countenanced and, furthermore, any leakage from the surge-shaft base would undoubtedly have found its way to the mountain side and have caused serious slips, endangering the whole scheme. Dr. Gruner, an eminent authority on pressure tunnels, was consulted, and the chamber was constructed according to his design, which consists of a cage of steel reinforcing-rods with steel-rod ties carried back into the main tunnel and the two pipe tunnels, the whole being gunited in place.

The power house is situated on the banks of the Neri Khad, and is designed for the ultimate accommodation of seven 12,000-kilowatt generators and their necessary switchgear. The building is of the earthquake-proof type, the entire structure being carried by heavy steel stanchions founded on a mat of concrete which is 12 feet thick and is continuous throughout its length under the machinery hall and control block. The walls are merely partitions between the stanchions and consist of cement plaster on expanded metal. They are designed for a wind pressure of 25 lb. per square foot. The design is based on a seismic acceleration of 32 feet per second per second. There are four generators, each o

[1] G. H. Hunt, R. D. Keane, and N. V. Dorofeeff, "Tunnelling in Connection with the Uhl River Hydro-Electric Project." Proc. Punjab Engineering Congress, vol. x (1932), p. 35.

12,000 kilowatts output, and each directly connected to 17,000-brake-horsepower Boving impulse turbines of the overhung type with a speed of 425 revolutions per minute. They are equipped with high-speed excitation. The voltage of generation is 11,000 and this is stepped up to 132,000 for transmission to Amritsar, Lahore, and Jullundur, from which places 66,000-, 33,000- and 11,000-volt branch-lines radiate, making supply available in twenty-four towns and a rural area of approximately 20,000 square miles.

After installation, tests were carried out on both generators and turbines; the method employed in measuring the water was the subject of a Paper[1] by Mr. E. N. Webb, M. Inst. C.E. The results of these tests are briefly tabulated as follows:—

	Machine No. 1: per cent.	Machine No. 2: per cent.	Machine No. 3: per cent.	Machine No. 4: per cent.
Turbine efficiency . . .	88·60	88·60	88·10	88·9
Generator efficiency . .	96·5	96·5	96·5	96·3

The outlay on production works was 26,135,285 rupees and the installed capacity of the plant is, at present, 48,000 kilowatts, indicating an installation cost per kilowatt of 545 rupees; although this may appear high, it must be remembered that the headworks, tunnel, and surge shaft are all built to a design which makes them capable of passing sufficient water for the development of a total of 72,000 kilowatts. Furthermore, the footings of the anchors for the next two pipe-lines have been completed, which means that the capital expenditure of 26,135,285 rupees includes an amount of 9,000,000 rupees which has been expended on behalf of the second stage, so that this second stage may be constructed without interruption to supply, and so as to take advantage of the greater efficiency and lesser cost due to the construction being undertaken in conjunction with the first stage works. Taking this figure into account, the installation cost per kilowatt may be said to be 357 rupees. The cost per unit generated, even including the full capital expenditure made to date, works out at 2·5 pies (a pie is approximately $\frac{1}{12}$ penny) and will be proportionately lower for the second and third stages. The average return obtained, at present, is 11 pies per unit sold and the load connected after 5 years' operation exceeds 30,000 kilowatts. Additional generating capacity will be necessary to meet the fast increasing demand in the year 1942, and proposals for suitable extensions are being considered.

The Paper is accompanied by two sheets of illustrations, from one of which the Figure in the text has been prepared.

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[1] "Efficiency Tests of Large Modern Pelton Wheels." Journal Inst. C.E., vol. 4 (1936–37), p. 259 (December, 1936).

Paper No. 5240.

"Discharge by Surface Floats."

By WILLIAM MAURICE GRIFFITH, Assoc. M. Inst. C.E.

(*Ordered by the Council to be published with written discussion.*)[1]

THE object generally aimed at in river and canal gauging operations is to establish a means of computing the daily rate of flow.

At sites where the discharge is a reasonably stable function of the water-level, these operations aim at establishing this function as accurately as is possible, so that the daily discharge can be computed from the water-levels.

The usual method of establishing the function is to observe, by means of a current-meter, the discharges flowing at different water-levels throughout the range required, plotting these observed discharges against water-levels, and drawing a smooth curve through the points. The curve so drawn is called the "stage-discharge curve" or sometimes the "normal discharge curve."

In a canal where the discharge is controllable this can be done quickly, but in a river it may be years before discharges can be observed over the full range of water-levels required, and during this period the river-section may alter, which will largely vitiate the value of the operations. As the velocity of flow varies as the square root of the depth of flow, the equation for a stage-discharge curve of a channel will be of the general form

$$Q = C \cdot \Delta \cdot \sqrt{D - d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where Q denotes the discharge, Δ the sectional area of flow, D the gauge reading, and d denotes the approximate gauge reading at which the discharge becomes zero, and C is the coefficient of discharge at that site. As Δ is measurable, this equation contains only two unknowns, C and d, so that an approximate stage-discharge curve can be obtained from two reasonably accurate discharge observations, provided that these are for materially different values of D. As an example, consider the stage-discharge curve recently established for the river Severn at Bewdley by means of fifty-nine discharge measurements [2].

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[1] Correspondence on this Paper can be accepted until the 15th June, 1941, and will be published in the Institution Journal for October 1941.—SEC. INST. C.E.

[2] S. M. Dixon, G. Fitzgibbon, and M. A. Hogan, "The Flow of the River Severn, 1921–36." Journal Inst C.E., vol. 6 (1937), p. 81, June 1937.

Table I, column (4), gives the values of the discharges Q scaled from this stage-discharge curve for six different values of the gauge D, ranging from 8·0 feet to 18·0 feet. Selecting two from this table, namely No. 1 ($D = 8{\cdot}0$ feet, $\Delta = 900$ square feet, $Q = 2{,}050$ cusecs) and No. 5 ($D = 16{\cdot}0$ feet, $\Delta = 2{,}230$ square feet, and $Q = 10{,}600$ cusecs), then substituting these values in equation (1), gives

$$2{,}050 = 900C\sqrt{8 - d}$$

$$10{,}600 = 2{,}230C\sqrt{16 - d}$$

Solving this, $C = 1{\cdot}475$ and $d = 5{\cdot}615$.

Substituting these values in equation (1), the equation for the stage-discharge curve becomes

$$Q = 1{\cdot}475\Delta\sqrt{D - 5{\cdot}615} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

TABLE I.

Serial No. (1)	D Gauge reading: feet. (2)	Δ Cross-section area: square feet. (3)	Q Discharge: cusecs. (4)	Discharge by equation (2): cusecs. (5)	Difference: cusecs. (6)	Percentage of difference. (7)
1	8·0	900	2,050	2,050	0	0·00
2	10·0	1,215	3,600	3,753	+ 153	+ 4·25
3	12·0	1,520	5,500	5,666	+ 166	+ 3·02
4	14·0	1,860	8,000	7,945	− 55	− 0·69
5	16·0	2,230	10,600	10,600	0	0·00
6	18·0	2,600	13,665	13,495	− 170	− 1·24

In Table I, column (5), are given the values found by this equation, and a comparison of these values with those in column (4) shows that there is not a great difference between this stage-discharge curve found from two accurate observations and that found from the fifty-three observations.

If the value of d is known from observation of dry summer-flow, an approximate stage-discharge curve can be found for one observed discharge.

In computing daily discharges from water-levels by means of a stage-discharge curve, inaccuracy, due to small variations in sectional area resulting from periodic scour or accretion of the channel-section, can be met by adopting a system of periodic check discharges, and using a percentage factor with the stage-discharge curves, which the check-observations indicate to be necessary from time to time.

In the rivers of the Great Ouse Catchment Board area, the discharge is, in general, not a stable function of the water-level, for the following reasons:—(a) in the lower reaches flow is tidally affected; (b) in the upper reaches it is usually affected by the control of a lock or mill-sluices; (c) where a reach is found unaffected by sluices, the rapid and heavy

growth of weeds in the summer season often makes any satisfactory co-ordination between water-levels and discharge impossible.

At the sites of weirs and sluices, computation of the discharge from data of upstream and downstream water-levels and gate-openings is possible, though laborious, in the summer season; but as, in time of flood, sluices are raised clear of the water-level, and in high floods the sluices and weirs are often out-flanked by flood-water. it is not possible to compute the daily discharges by the ordinary methods.

The Author has to compute the daily discharges at twenty-five such sites on the river Ouse and its tributaries to provide data for the work of designing improvements in the upper reaches and outfall of the river Ouse, and to supply data for working the tidal-model.

No satisfactory co-ordination between water-level and discharge being possible at these sites, it has been necessary to adopt a special method to obtain the daily discharges, which is described in this Paper. Under the conditions stated, great accuracy of computation of individual discharges cannot be looked for, but fortunately this is not required, provided the errors are such that they tend to balance out over a series of observations, and it is claimed that this result is secured by the Author's method.

In principle the method consists in obtaining daily, at carefully selected sites, the maximum surface velocity of the flow by timing a float, and the water-level by reading a gauge; the discharge is computed from these two observations by means of a table.

In computing discharges by means of a stage-discharge curve, it is assumed that the mean velocity of flow is a stable function of the gauge reading. In the Author's method, it is assumed only that the ratio of maximum surface velocity to mean velocity is a stable function of the gauge reading. The Author considers that this assumption is justified if the site is such that there is streamlined flow at all gauges.

To explain this more clearly, sinuous or turbulent flow may be divided into two classes :—

(*a*) "Streamlined" flow, in which condition the lines of flow are approximately parallel and follow the boundary surfaces.

(*b*) "Non-streamlined" flow, occurring where the deviation of the boundary surfaces from the straight is too rapid for the lines of flow to follow. In this condition, loss of head by shock occurs, the energy being dissipated by vortices.

By "streamlined flow" is meant flow within streamlined boundary surfaces and not laminar flow.

To ensure streamlined flow, therefore, it is necessary to select a site of observations where the river is approximately straight, the sides are parallel, and the bed is fairly level.

If V_s denote the maximum surface velocity, V_m the mean velocity of

the flowing section, Δ the sectional area of flow, and f the ratio $\frac{V_m}{V_s}$, then the discharge

$$Q = V_m \Delta = V_s f \Delta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Now if f varies with the gauge it varies with Δ, and $f\Delta$ therefore has a fixed value for any water-level, designated the equivalent area.

If values of $f\Delta$ are known and tabulated for different water-levels, the discharge can be computed at once from the daily observations of the water-levels and the maximum surface velocity V_s.

The values of $f\Delta$ can, of course, be obtained for any discharge site by a series of rating observations with a current-meter in the same way that a stage-discharge curve is obtained; but this method is laborious and unnecessary, as the value of f has already been established by Bazin.

Bazin gives his evaluation of f as $\dfrac{C}{C + 25{\cdot}4}$ . . . . (4)

where C is the coefficient in Chezy's fundamental formulas of flow.

Two objections have been raised to Bazin's evaluation, which have prevented a more general use of this equation: (1) that the correct computation of C in Chezy's formulas is controversial, Bazin having one valuation and Kutter another, and that in Bazin's evaluation of C, the limiting value of $f = 0{\cdot}86$, whilst Kutter's or Manning's evaluation is unity; (2) that Bazin's evaluation is based on sixty-one series of gauges and covers a wide range of hydraulic conditions for a normal regular cross-section; but it is generally accepted that Bazin's evaluation will not hold for an irregular cross-section, and in observing discharges of irregular cross-sections by surface floats the usual practice is to divide the irregular cross-sections into two or more regular sections by imaginary vertical planes, and to treat each section separately.

This entails obtaining the maximum surface velocity in each section. Some authorities carry this principle farther and divide a regular cross-section into a number of sections by imaginary vertical planes, spaced at equal intervals, observing the maximum surface velocity in each section separately.

Of these two objections the first is not serious, as, if Bazin's evaluation of f in terms of C is accepted, it is only logical also to accept Bazin's evaluation of C. Also Kutter's evaluation of C would introduce another variable, namely, the surface slope; so, using Kutter's evaluation of C in Bazin's formula

$$f = \frac{C}{C + 25{\cdot}4},$$

f would not be a stable function of the gauge reading.

The second objection is more serious, as although it is often possible

to select sites where the river has a regular cross-section under normal flow-conditions, many such sites have an irregular cross-section in times of high floods, and it would not be practicable to run a series of floats daily to obtain the maximum surface velocities in the several sections.

The problem of securing daily discharges at such sites, therefore, resolves itself into that of finding some method of amending Bazin's evaluation for f to make it applicable to irregular cross-sections.

In a Paper published by The Institution in 1927, the Author claimed [1] that in an unerodible cross-section the mean velocities in the verticals above points in the cross-section will tend to vary as the square root of the depths of these points.

Consider flow occurring in the irregular cross-section depicted in *Fig. 1.* This irregular cross-section can be divided into two regular sections AFGC, and CGHE by the imaginary vertical plane CG.

From the Author's hypothesis, the maximum velocity in these two sections must occur at the points of greatest depth, namely, at BF and DH, and consequently the maximum surface velocities will occur at B and D.

Fig. 1.

Again, if V_1 and V_2 denote the mean velocities in these verticals BF and DH, from this hypothesis,

$$\frac{V_1}{V_2} = \sqrt{\frac{\mathrm{BF}}{\mathrm{DH}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Let V_{s1} and V_{s2} be the surface velocities at B and D. It is reasonable to assume that the surface velocities at any vertical will vary with the mean velocities at that vertical, that is :

$$\frac{V_{s1}}{V_{s2}} = \frac{V_1}{V_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Therefore $\frac{V_{s1}}{V_{s2}}$ will be approximately $= \sqrt{\frac{\mathrm{BF}}{\mathrm{DH}}}$ . . . . (7)

If V_{m1} and V_{m2} denote the mean velocities of these two sections AFGC and CGHE respectively, and Δ_1 and Δ_2 their sectional areas, and

$$\frac{V_{m1}}{V_{s1}} = f_1 \quad \text{and} \quad \frac{V_{m2}}{V_{s2}} = f_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

[1] "A Theory of Silt and Scour." Minutes of Proceedings Inst. C.E., vol. 223 (1927), p. 243.

then the discharge of the whole section

$$
\begin{aligned}
&= V_{m1}\Delta_1 + V_{m2}\Delta_2 \\
&= V_{s1} f_1\Delta_1 + V_{s2} f_2\Delta_2 \\
&= V_{s1} f_1\Delta_1 + \sqrt{\frac{\mathrm{DH}}{\mathrm{BF}}} \times V_{s1} f_2\Delta_2 \\
&= V_{s1}\left\{f_1\Delta_1 + \sqrt{\frac{\mathrm{DH}}{\mathrm{BF}}}(f_2\Delta_2)\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)
\end{aligned}
$$

The values of the expression

$$\left\{f_1\Delta_1 + \sqrt{\frac{\mathrm{DH}}{\mathrm{BF}}}(f_2\Delta_2)\right\}$$

can be computed from the cross-section and Bazin's evaluation of f, and tabulated in terms of the gauge reading, in the same way as the values of $f\Delta$ can be found and tabulated in terms of the gauge for a regular cross-section, so that the discharge of both a regular and an irregular cross-section can be computed by this method if the maximum surface velocity of the main stream and the gauge be observed.

In the above example the irregular cross-section has been divided into only two regular cross-sections, but the same method is applicable if it is necessary to divide the irregular cross-section into more than two sections to obtain regular cross-sections.

If d_1 denote the maximum depth of the main stream and $d_2, d_3, \ldots d_n$ the maximum depths of the subsidiary sections into which the whole cross-section is subdivided, and if $\Delta_1, \Delta_2, \Delta_3. \ldots \Delta_n$ denote the sectional areas and $f_1, f_2, f_3, \ldots f_n$ the ratio of mean to maximum surface velocities of these sub-sections, then by the same reasoning the discharge of the whole cross-section will be

$$V_{s1}\left\{f_1\Delta_1 + \sqrt{\frac{d_2}{d_1}}(f_2\Delta_2) + \sqrt{\frac{d_3}{d_1}}(f_3\Delta_3) + \ldots + \sqrt{\frac{d_n}{d_1}}(f_n\Delta_n)\right\}.$$

where V_{s1} denotes the maximum surface velocity of the main stream. Values of

$$\left\{f_1\Delta_1 + \sqrt{\frac{d_2}{d_1}}(f_2\Delta_2) + \sqrt{\frac{d_3}{d_1}}(f_3\Delta_3) \ldots + \sqrt{\frac{d_n}{d_1}}(f_n\Delta_n\right\}$$

can be calculated from the cross-sections and tabulated in terms of the gauge reading.

Table II gives the values of f for different conditions of roughness for different values of R, the hydraulic mean depth.

Figs. 2 show cross-sections at the discharge-site of the river Little Ouse, and the values of R, Δ and f and $f\Delta$ are tabulated for every foot of gauge-reading in Table III. These values of $f\Delta$ may be plotted against

gauge-reading, and from the smooth curve thus obtained the values of $f\Delta$ for every inch of gauge-reading may be tabulated.

TABLE II.

Hydraulic mean depth R: feet.	Value of f for channels in:			
	Smooth cement-plaster.	Brickwork or rough concrete.	Rubble masonry.	Earth channels in ordinary conditions.
0·5	0·844	0·784	0·739	0·593
1·0	0·848	0·806	0·772	0·649
1·5	0·851	0·817	0·787	0·680
1·75	0·852	0·819	0·793	0·691
2·0	0·853	0·821	0·796	0·699
2·5	0·854	0·824	0·803	0·715
3·0	0·854	0·828	0·809	0·725
4·0	0·855	0·833	0·815	0·740
5·0	0·856	0·836	0·820	0·752
6·0	0·856	0·838	0·823	0·759
8·0	0·856	0·841	0·828	0·772
10·0	0·857	0·843	0·832	0·781
12·0	0·857	0·844	0·834	0·787
15·0	0·857	0·846	0·836	0·794
20·0	0·858	0·849	0·839	0·803
30·0	0·859	0·851	0·842	0·813
50·0	0·860	0·853	0·847	0·824

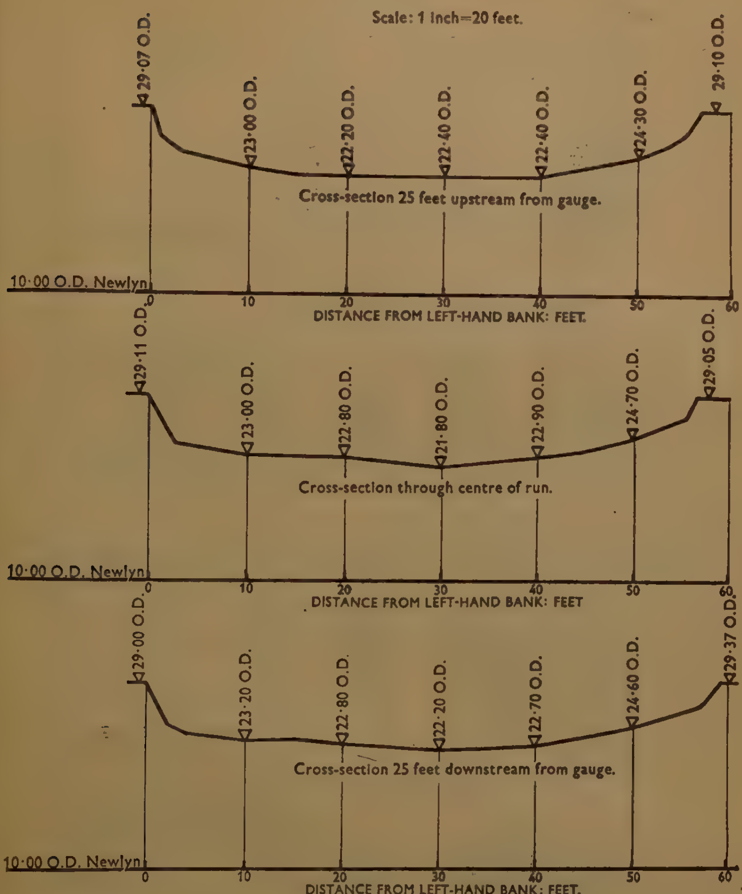
Fig. 3, p. 292, shows a cross-section of the river Great Ouse below Brownshill staunch, which has a regular cross-section (shown on the left side of the cross-section) for low gauges, but at high gauges flow occurs across the wide washland area on the right-hand side and between the

TABLE III.

Gauge reading: feet.	Mean sectional area, Δ: square feet.	Mean wetted perimeter: feet.	Mean R: feet.	f.	$f\Delta$.
24	56	42	1·33	0·670	37·6
25	103	47	2·20	0·707	72·8
26	153	52	2·94	0·724	111·0
27	208	55	3·80	0·739	153·8
28	265	57	4·65	0·748	199·0
29	322	59	5·47	0·755	243·0

two flood-banks shown at the extreme right and left of the section. These flood-banks are parallel, so that in general there is streamlined flow. This cross-section is divided into two sections by the vertical AA. The areas of the main river section which lies to the left of AA are classed as Δ_1, and the remainder as Δ_2.

Fig. 2.



Cross-Sections of the Little Ouse at the Discharge-Site.

In Table IV, values of Δ, R, and f for these two sections are given. The last column of Table IV gives values of $f\Delta$ for the whole section which

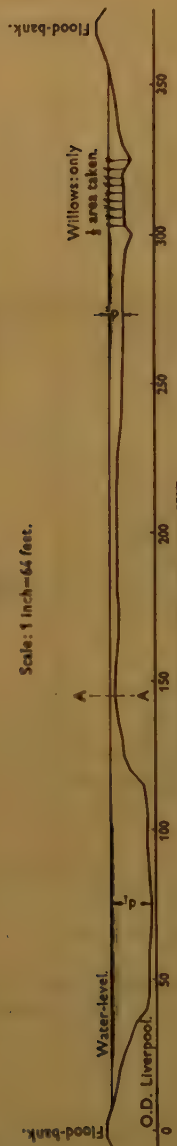
$$=f_1\Delta_1+\sqrt{\frac{d_2}{d_1}}\,(f_2\Delta_2).$$

These values of $f\Delta$ are plotted against the gauge-reading, and from them the discharge may be computed in terms of one float-run, that is, along line d_1, whether the river is in flood or not.

Experience shows that, given a well-selected site and a calm day, discharges can be computed very accurately by this method, but it is essential that the site be well selected to ensure streamlined flow, as a

Fig. 3.

Scale: 1 inch=64 feet.



CROSS-SECTION OF THE GREAT OUSE BELOW BROWNSHILL STAUNCH.

TABLE IV.

Gauge reading:	Areas:		Maximum depth:		Coefficient:		$f\Delta = f_1\Delta_1 + \sqrt{\frac{d_2}{d_1}}(f_2\Delta_2)$.
feet.	Δ_1: square feet.	Δ_2: square feet.	d_1: feet.	d_2: feet.	f_1.	f_2.	
9	563	0	7·5	—	0·766	—	430
10	660	32	8·5	—	0·774	—	510
11	768	89	9·5	0·5	0·776	0·60	608
12	878	167	10·5	1·5	0·778	0·69	728
13	998	313	11·5	2·5	0·780	0·71	882
14	1,130	501	12·5	3·5	0·781	0·73	1,075
15	1,264	689	13·5	4·5	0·782	0·75	1,286
16	1,402	880	14·5	5·5	0·783	0·76	1,513

projection creating dead-water at some point will produce a serious error in the Bazin evaluation of f.

The most disturbing factor in practice is the action of wind on the float and on the water-surface. The error resulting from this factor varies

TABLE V.—DISCHARGE OBSERVATIONS BY CURRENT-METER AND SURFACE FLOATS.

Date of observation.	Discharge sill.	Observed discharge: cusecs.		Percentage of difference.	Discharge by maximum surface velocity as measured by Watts' meter.	Percentage of difference.	Remarks.
		By current-meter.	By single surface-float.				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3/4/37	River Ouse at Brownshill Staunch—Gauge, 12 feet 6 inches	1002	1035	+ 2·2	Not taken		Irregular flooded section.
20/4/37	River Ouse at Brownshill Staunch—Gauge, 14 feet 2 inches	2092·4	2380	+ 13·5	2050	− 1·5	ditto.
21/4/37	River Ouse at Bedford	1670·7	1856	+ 11·1	1540	− 7·8	ditto.
28/5/37	River Ouse at St. Neots	2516·7	2525	+ 0·3	2200	− 12·5	ditto.
16/6/37	River Nar at Wormegay High Bridge	54·6	50·8	− 7·0	51·0	− 6·6	ditto.
26/2/37	River Ouse at Brownshill Staunch—Gauge, 14 feet	2963·7	*3070	+ 3·7	Not taken		ditto.
1/2/39	River Ouse at Brownshill Staunch—Gauge, 15 feet 3 inches	3628	3640	+ 0·3	4060	+ 11·9	ditto.

* Discharge taken by four surface-floats in different sections.

directly as the velocity of the wind and inversely as the velocity of the water.

A series of experiments made in a still-water lake at Bedford showed that a float consisting of a piece of light pinewood will travel three times as fast under the action of wind as will a weighted float consisting of a rod of the same wood, 9 inches long, weighted at one end so as to float in a vertical position with 8 inches of its length submerged, and 1 inch only above the water-surface.

In consequence weighted floats are now in general use at the Great Ouse Catchment Board discharge-sites. These cost about 4*d*. per dozen, and are usually not recovered.

Errors due to wind-action usually balance out to a certain extent in a series of daily observations, as the wind is not always in one quarter.

The extent of accuracy that observations taken by this method may be expected to give, can be judged from Tables V, VI, and VII, which give the results of check of these observations by (*a*) current-meter observations, (*b*) discharges computed from weir and sluice formulas, and (*c*) discharges computed by surface-floats at two different sites on the same river, so near to each other that there can be no material change in the river-discharge between the sites.

The Paper is accompanied by two sheets of drawings, from some of which the Figures in the text have been prepared.

TABLE VI.—DISCHARGE OBSERVATIONS AT BEDFORD BY WEIRS AND FLOATS.

Date.	Discharge by weirs: cusecs.	Discharge by floats: cusecs.	Difference: cusecs.	Percentage of difference.
1938				
14th Jan.	1,005	1,024	+ 19	+ 1·9
17th ,,	1,149	1,140	— 9	— 0·8
18th ,,	1,180	1,152	— 28	— 2·4
19th ,,	1,279	1,242	— 37	— 2·9
20th ,,	1,123	1,149	+ 26	+ 2·3
27th ,,	437	390	— 47	— 10·8
28th ,,	477	448	— 29	— 6·1
31st ,,	1,121	1,043	— 79	— 7·0
1st Feb.	1,306	1,302	— 4	— 0·3
2nd ,,	1,354	1,295	— 9	— 0·6
3rd ,,	1,185	1,134	— 51	— 4·2
4th ,,	853	872	+ 19	+ 2·2
5th ,,	553	495	— 58	— 10·4
12th Dec.	1,113	1,050	— 63	— 5·7
13th ,,	1,220	1,070	— 150	— 12·3
28th ,, } 29th ,,	1,990	2,002	+ 12	+0·6
1939				
4th Jan.	1,690	1,660	— 30	— 1·8
5th ,,	1,280	1,230	— 50	— 3·9
6th ,,	1,020	930	— 90	— 8·8
7th ,,	1,005	922	— 83	— 8·3
9th ,,	2,360	2,240	— 120	— 5·1
10th ,,	1,770	1,690	— 80	— 4·5
11th ,,	1,375	1,395	+ 20	+ 1·5
14th ,,	1,295	1,133	— 162	— 12·5
16th ,,	1,100	1,068	— 32	— 2·9
17th ,,	1,520	1,470	— 50	— 3·3
18th ,,	1,750	1,750	—	—
19th ,,	2,225	2,204	— 21	— 0·9
20th ,,	2,050	2,020	— 30	— 1·5
21st ,,	1,790	1,770	— 20	— 1·1
23rd ,,	1,944	1,915	— 29	— 1·5
24th ,,	1,840	1,855	+ 15	+ 0·8
27th ,,	2,680	2,530	— 150	— 5·6
Total	45,039	44,588	— 1,400	— 3·1
	Discharge on River Lark (Tollgate).			
	30·82	31·06	0·24	+ 0·77
	Flempton Lock.			
	29·58	29·20	0·38	— 1·31
1939 19th April	Discharge of River Cam at Bottisham Lock.			
	121·6	119	2·9	— 2·4

TABLE VII.—COMPARISON OF DISCHARGES ON RIVER LITTLE OUSE BETWEEN DISCHARGE-SITES AT (A) 2 FURLONGS BELOW THETFORD TOWN BRIDGE, (B) 180 YARDS BELOW THETFORD No. 1 STAUNCH.

Date: Dec. 1939.	Gauge reading.	Time for 50-foot run: seconds.	$f\Delta$.	Working.	Discharge: cusecs.	Gauge reading.	Time for 50-foot run: seconds.	$f\Delta$.	Working.	Discharge: cusecs.	Difference in discharge: cusecs.
	Site A.					Site B.					
15th	28 feet 2 inches	19 20 19	147·7	$\frac{147{\cdot}7 \times 50}{19}$	388	26 feet $8\frac{1}{2}$ inches	18 18 18	142·0	$\frac{142 \times 50}{18}$	394	+ 6
20th	28 feet 1 inch	29 28 26 28	144·0	$\frac{144 \times 50}{28}$	257	25 feet $10\frac{1}{2}$ inches	20 22 21	106·5	$\frac{106{\cdot}5 \times 50}{21}$	256	− 1
21st	27 feet 6 inches	25 25 25	118·5	$\frac{118{\cdot}5 \times 50}{25}$	237	25 feet 9 inches	22 22 22	102·0	$\frac{102 \times 50}{22}$	232	− 5
									Total difference in three readings .		0

(1) Weighted floats were used. Times were taken with a stop-watch.
(2) Readings were taken on still days.
(3) Gates at No. 1 staunch in various positions.
Note.—The differences between discharges at the two sites cancel each other out.

Paper No. 5242.

"An Apparatus for Measuring the Lateral Pressure of Clay Samples under a Vertical Load." [1]

By Geoffrey Morse Binnie, M.A., Assoc. M. Inst. C.E., and John Alfred Price, B.A., Stud. Inst. C.E.

(*Ordered by the Council to be published with written discussion.*)

TABLE OF CONTENTS.

Introduction.

Dr. Karl von Terzaghi, M. Inst. C.E., in his recent James Forrest lecture [2], concluded that earth-pressure theories can never be applied to clay, and that "the pressure of clay on lateral supports can only be learned from experience, to be acquired by actually measuring the pressure in different cuts and correlating the results with complete quantitative data regarding the nature of the soils investigated."

It is suggested that if any complete systematic study of earth-pressures in the field, accompanied by laboratory investigations, is ever to be made, information would be required on the ability of the soil to exert lateral pressure under a vertical load, and on the manner in which the lateral pressure is influenced by moisture-content and elastic properties.

The machine now described was designed with this object in view.

Design.

The lateral pressure of clay under a vertical load, as influenced by its moisture-content and elastic properties, will be referred to as the elastic lateral pressure. The difficulty experienced in designing a machine of this type is to devise some accurate means of measuring the lateral

[1] Correspondence on this Paper can be accepted until the 15th June, 1941, and will be published in the Institution Journal for October 1941.—Sec. Inst. C.E.

[2] "Soil Mechanics. A New Chapter in Engineering Science." Journal Inst. C.E., vol. 12 (1938–39), p. 113 (June 1939).

pressure without allowing any lateral movement of the clay to take place. Any such movement will affect the reading to a certain extent, and the greater the movement the more can the observed lateral pressure be expected to depart from the true elastic lateral pressure.

Although absolute rigidity cannot be claimed for the machine, the movement required to record the lateral pressure has been reduced to less than $\frac{1}{1000}$ inch.

The principle of the machine is similar to that of Dr. von Terzaghi's tape, in that it depends upon the measurement of friction between metal parts under load; but whereas the tape is based upon sliding friction, the machine depends upon the friction of a rotating shaft between two bearing surfaces, the friction being calibrated by means of water-pressure.

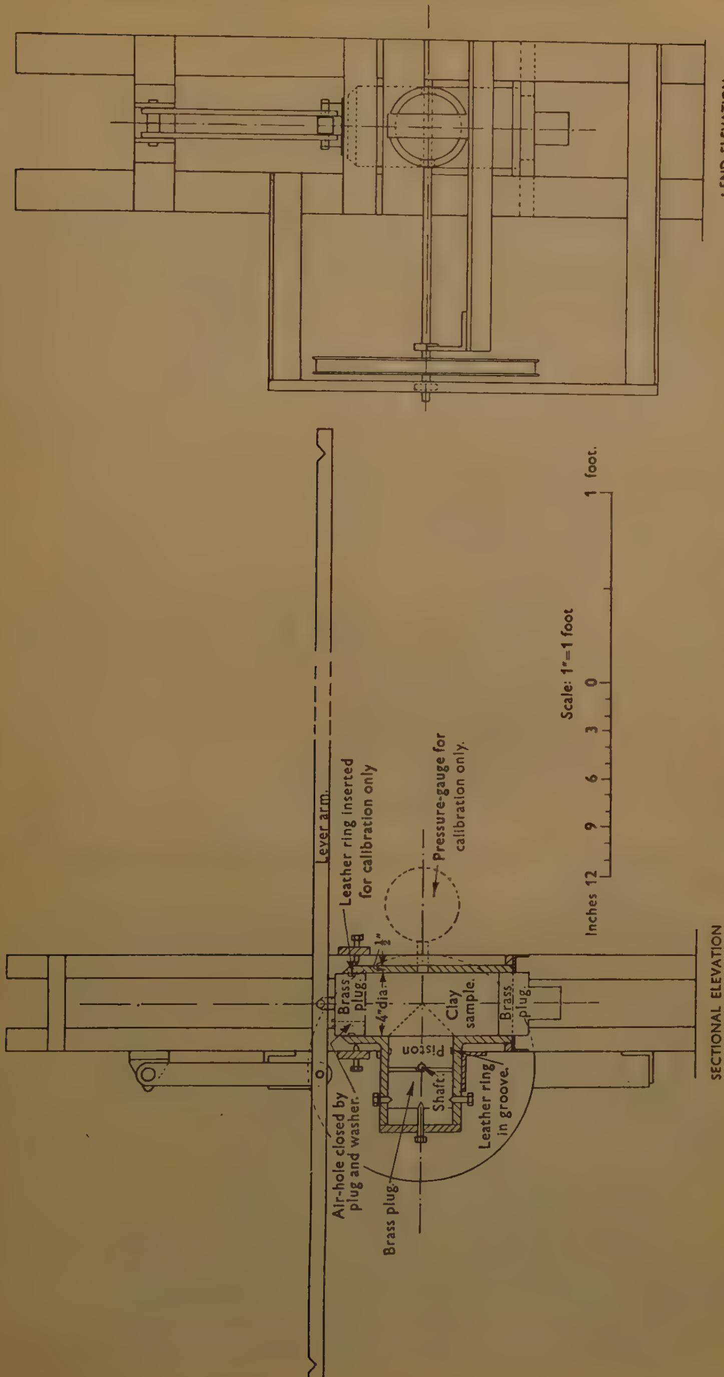
The machine is shown in *Fig. 1.* A thick brass pipe 4 inches in internal diameter has a branch of equal diameter at right-angles to it. In the branch is a brass piston which is a sliding fit. A leather ring, which acts as a water-stop, is inserted in a circumferential groove round the piston. One face of this piston is curved to a 2-inch radius, so that when in position in the branch, the pipe becomes a cylinder with a false side. The other face of the piston is plane, with a $\frac{1}{2}$-inch-diameter semi-circular groove cut in it. One end of a $\frac{1}{2}$-inch-diameter stainless-steel shaft runs in this groove between the piston and a plane-faced brass plug. A 14-inch-diameter pulley-wheel is mounted on the other end of the shaft, between two self-aligning ball-bearings.

The plug is brought into position by means of an adjusting screw, so that the curved face of the piston forms a smooth surface with the sides of the cylinder. It is then held in position by eight set-screws around the circumference, the ends of the screws projecting into holes previously drilled in the sides of the plug while in its correct position. A threaded plug, similar to the one shown at the bottom of the cylinder, would have been an improvement on the set-screws.

It can be seen that any pressure on the piston is transmitted to the shaft in the form of reaction against the bearing-surfaces formed by the piston groove on one side and the plane surface of the brass plug on the other side. This reaction induces a frictional resistance to any rotation of the shaft. Thus, by measuring the torque required to turn the shaft, an indication can be obtained of the pressure exerted on the piston. This torque is measured by means of a cord around the pulley carrying weight-pans, one of the pans being loaded until the shaft just begins to rotate. In order to eliminate any variation of the friction due to unevenness of the shaft, the pulley-wheel is always brought back to the same position each time the pans are loaded.

The whole apparatus is rigidly mounted on a heavy steel framework. The threaded plug at the bottom of the cylinder facilitates the removal of samples after testing.

Fig. 1.

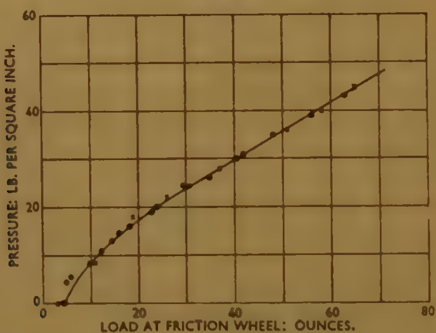


General Arrangement of Apparatus.

Calibration.

The machine is calibrated as follows: a water-pressure gauge is screwed into a hole tapped in the side of the cylinder. When not in use, this hole is closed with a plug. The cylinder is filled with water. A brass cap with a leather ring in a circumferential groove is fitted into the top of the cylinder. Air trapped underneath the cap is allowed to escape through a small hole drilled through the cap, a plug being screwed into the hole afterwards. A vertical load is then applied to the top of the plug by means of a lever-arm. The water-pressure inside the cylinder is observed on the pressure-gauge, and simultaneously the load required to rotate the stainless-steel shaft is noted. This process is repeated for a series of loads. During this process the cap sinks slowly as the water leaks past it, but the lever-arm maintains the water-pressure. A sufficient

Fig. 2.



number of readings to plot a complete calibration curve can be obtained in about 20 minutes.

A typical calibration curve is shown on *Fig. 2.* For lateral pressures below 10 lb. per square inch the readings were generally erratic, and the smaller values were usually ignored. As shown on the graph, a straight-line relationship between friction and lateral pressure was obtained for the higher values.

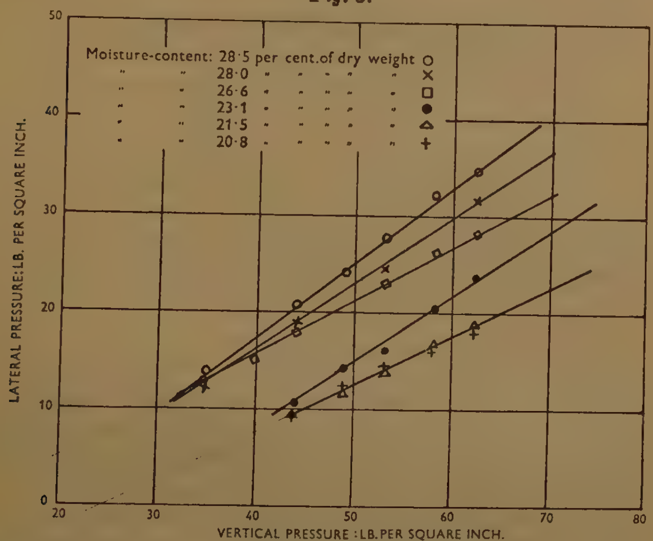
The curves varied a little in the course of time. This was attributed partly to dust getting into the bearings, and partly to the steel shaft bedding itself slightly against the plane-surface of the plug. After the shaft had been in use for some time, it was observed that a line was scoured across the face of the plug where the shaft had been bearing against it. This scouring could probably have been rectified by inserting a circular disk about 1 inch thick with a ½-inch-diameter groove across it in between the shaft and the plug, so that the shaft would have had a curved bearing-surface on both sides. Nevertheless, by calibrating the machine immediately before and after use, and taking a mean between the two curves,

it was possible to obtain readings with an error probably not exceeding ± 5 per cent.

Experiments.

In order to try out the machine, quick tests were carried out on six cores obtained from the Blue Lias clay at the laboratory site. Steel tubes approximately 4 inches in diameter were split longitudinally, and the two halves were held together by a collar at the upper end and by wire in circumferential grooves at intervals along the length. The cores were obtained by driving these tubes into the ground, the lower ends being sharpened to cutting-edges. The cutting-edges were turned in so that the samples obtained were slightly smaller than the interior of the

Fig. 3.



tubes, to reduce friction. The top and bottom of each core were cut off square with a knife, and the core was slipped into the machine. The cores obtained were actually slightly larger than 4 inches in diameter, and the top cutting-edge on the machine trimmed off the sides so that a tight fit against the sides of the cylinder was obtained. An analysis of the Blue Lias clay in the neighbourhood is given in Appendix A.

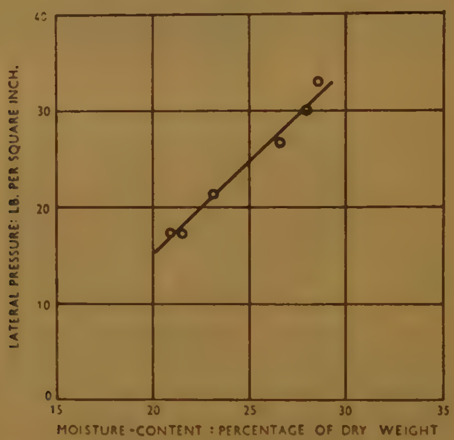
The vertical load was applied to the cores by means of the lever-arm acting on top of the brass cap (the leather ring being removed), and the readings were taken soon after each load was applied. The results are plotted in *Fig. 3*, which shows the influence of the moisture-content upon the lateral-pressure readings. The moisture-content is expressed as a percentage of the dry weight of the clay.

The effect of moisture-content is further illustrated by *Fig. 4* which shows the variation of lateral pressure of the clay under a vertical load of 60 lb. per square inch for different moisture-contents.

Experiments were also carried out on the Blue Lias clay after it had been passed through a pug-mill, which was being used for the construction of a corewall for an earth dam. In this case the clay was hand-packed into the machine.

The increase in elastic lateral-pressure due to puddling is well illustrated by *Fig. 5*, which shows the results obtained from one of the puddled-

Fig. 4.



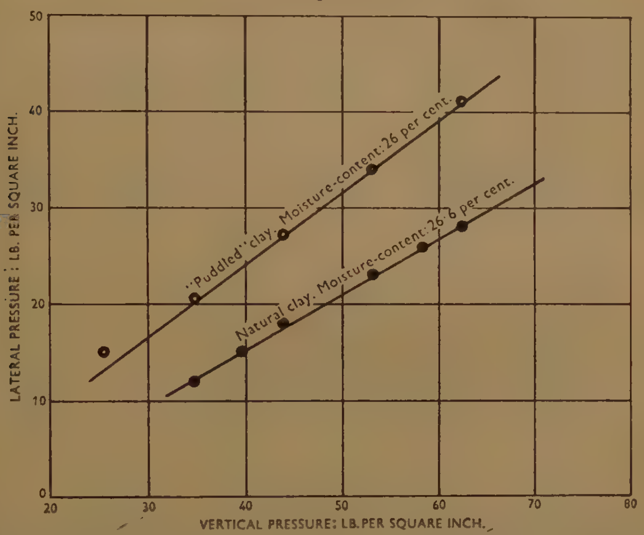
clay samples compared with one of the cores with approximately the same moisture-content. This increase in lateral pressure is to be expected from the re-moulding effect obtained as a result of passing the clay through the pug-mill.

An experiment was also carried out on a re-moulded sample of saturated Blue Lias clay to investigate the variation of lateral pressure in relation to time and the rate of consolidation. As shown on the cross-section in *Fig. 6*, a porous stone was inserted above and below the clay. Water was able to enter and leave the soil-sample by means of a funnel and a rubber pipe connected to a hole drilled through the side of the machine, which gave free access of the water to a grid placed below the bottom stone. An Ames dial mounted above the bronze cap recorded the degree of consolidation.

The clay sample was prepared for the test by subjecting it to vertical loads of 5 lb. per square inch and 10 lb. per square inch in a saturated condition, complete consolidation being allowed to take place under the first load before the second load was applied. After complete consolidation had taken place under the second load, the load was increased to

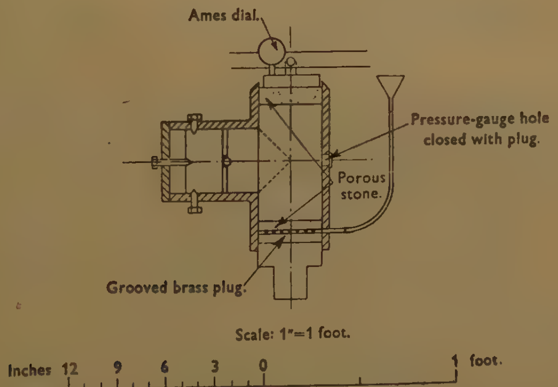
21·4 lb. per square inch, and simultaneous lateral-pressure and consolidation readings were taken at regular intervals. When consolidation under

Fig. 5.



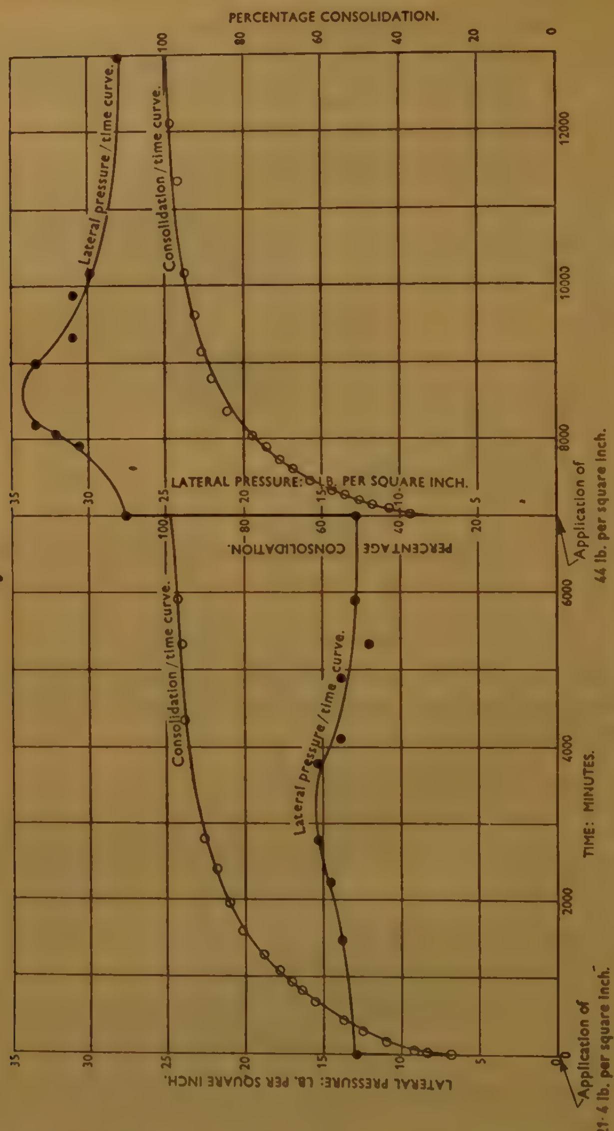
this load was complete, the load was again increased to 44 lb. per square inch and the readings were continued until complete consolidation had taken place as before.

Fig. 6.



The experiment took approximately a month to complete. *Fig.* 7 shows the results obtained in this experiment, and the specimen-curve in *Fig.* 2 shows the calibration of the apparatus before and after the experiment. The readings and details are given in Appendix B.

Fig. 7.



VARIATION OF LATERAL PRESSURE AND CONSOLIDATION OF CLAY WITH TIME.

It is interesting to note that under both vertical loads the lateral pressure increased initially to approximately 60 per cent. of the applied vertical load, then increased to approximately 75 per cent. of the applied load when consolidation was 85–90 per cent. complete, and finally decreased again to its original value of approximately 60 per cent. of the applied load.

Conclusion.

It is much regretted that the war has prevented any further research. The experiments, although far too limited in number for any definite conclusions to be drawn about the elastic lateral-pressure properties of clay under a vertical load, fulfilled their primary object in showing the possibilities and scope of the machine.

The Paper is accompanied by six sheets of drawings, from which the Figures in the text have been prepared, and by the following Appendixes.

APPENDIX A.

Notes on Tests on a Sample of Lias Clay from Eye Brook Dam, near Kettering carried out by the Department of Scientific and Industrial Research at the Building Research Station, Garston, Herts.

The following is a brief record of the results obtained.

Description of Sample.
The sample consisted of blue-grey clay in a plastic condition which had been taken from the puddle-trench, the puddle having been prepared from the Lias clay occurring at the site.

Identification Tests.
The following tests were carried out on the sample to identify the type of soil.

(*a*) *Mechanical analysis.*—The particle-size distribution was determined by the standard method of mechanical analysis used at the Building Research Station. This involves pre-treatment with $\frac{N}{5}$ hydrochloric acid solution (to remove flocculating calcium salts) and with 6 per cent. hydrogen peroxide (to remove organic matter), followed by dispersion with $\frac{N}{100}$ sodium oxalate solution.

The following results were obtained :—

Fraction.	Size limits : diameter in millimetres.	Percentage.
Coarse sand	2–0·2	0
Fine sand	0·2–0·02	5·9
Silt	0·02–0·002	42·4
Clay	less than 0·002	50·2
Loss by pre-treatment	—	1·5

(*b*) *Atterberg Limit Tests.*—The Atterberg limit tests were carried out by the standard procedure with the following results :—

(1) Lower liquid limit	62·4 per cent.
(2) „ plastic „	22·6 „
(3) Plasticity index	39·8 „

(*c*) *Specific Gravity of Solids.*—The specific gravity of the solid material was determined by the standard method, using kerosene, as 2·715 grams per cubic centimetre.

Shear Tests.—Tests were carried out with the box-shear apparatus by the standard procedure employed at the Building Research Station, in which the clay is allowed to come to equilibrium in contact with water under various normal pressures. The specimens were prepared from the clay in the condition in which it was received, and the following results were obtained :—

Normal pressure : lb. per square inch.	Shear strength : lb. per square inch.	Initial moisture-content : percentage dry weight.	Final moisture-content : percentage dry weight.
7·8	5·4	32·4	28·9
15·1	8·8	32·4	28·6
23·6	11·8	31·9	27·2
31·1	13·5	32·8	27·2

These results can be represented approximately by a straight line relating the shear strength to the normal pressure, which cuts the shear-axis at 3·1 lb. per square inch, and has a slope of about 20 degrees.

APPENDIX B.

Details of Consolidation : Time Experiment on Blue Puddle-Clay.

Height of clay sample before consolidation	5·813 inches.
„ „ „ after „	5·305 „
„ „ „ after expansion	5·421 „
Weight of wet sample after expansion	2170 grams.
„ dried sample	1666 „
„ water	504 „
Specific gravity of soil-grains	2·715 grams per cubic centimetre.
Volume of sample	1118 cubic centimetres.
„ solid material	614 „ „
„ voids	504 „ „

Coefficient of consolidation C :—

For load 21·4 lb. per square inch, C was found to be $3{\cdot}73 \times 10^{-3}$ centimetres per minute.

For load 44 lb. per square inch, C was found to be $5{\cdot}84 \times 10^{-3}$ centimetres per minute.

Coefficient of compressibility A, the slope of the voids-ratio/pressure curve :

For load 21·4 lb. per square inch, A was found to be 0·053.

„ 44 lb. per square inch, A was found to be 0·037.

Paper No. 5239.

"General Properties of Parabolic Vertical Curves, with Special Reference to Road Design."

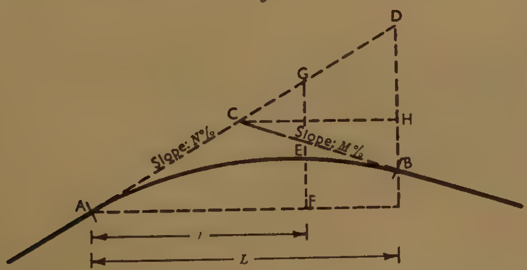
By Douglas William Mead Smith, B.Sc. (Eng.), Assoc. M. Inst. C.E.

(Ordered by the Council to be published in abstract form.)

A knowledge of the properties of the parabola, when applied intelligently, simplifies the solution of numerous problems in modern road design.

In the following formulas, a slope from the bottom left-hand corner to the top right-hand corner is considered to be positive, whilst that from the top left-hand corner to the bottom right-hand corner is considered to be negative.

Fig. 1.



In *Fig. 1* AC and BC are gradients of N per cent. and $-M$ per cent. respectively, the parabola AB being tangential at A and B to AC and BC. The horizontal distance between A and B is L feet.

E is any point on the parabola; AF, the horizontal distance of E from A, is l feet; and it is required to find y, the vertical distance EF of the point E above A.

BD is the vertical through B to meet AC produced in D, and CH is the horizontal through C to meet BD in H.

In road design, the error due to assuming that $\text{CH} = \dfrac{L}{2}$ is negligible, since the gradients are small.

$$\text{DB} = \text{DH} + \text{HB} = \frac{L}{2}\,\frac{(N - M)}{100}$$

and
$$\frac{\text{GE}}{\text{DB}} = \frac{l^2}{L^2}$$

that is,
$$GE = \frac{l^2}{2L}\,\frac{(N-M)}{100}$$

But
$$EF = FG - GE = \frac{lN}{100} - \frac{l^2}{2L}\,\frac{(N-M)}{100}$$

therefore
$$y = \frac{l}{100}\left\{N - \frac{l}{2L}(N-M)\right\}$$

If
$$x = \frac{l}{L}$$

then
$$y = \frac{l}{100}\left\{N - \frac{x}{2}(N-M)\right\} \quad . \quad . \quad (1)$$

This is the general equation of the parabola.

Therefore, if the actual level of point A be known, the actual level of any point on the curve can be determined.

Table I shows the method to be adopted to obtain the information required for setting out the curve. This Table is self-explanatory, but in setting out it should be borne in mind that distances must be measured horizontally.

Summits and valleys.

From equation (1), the slope at any point is given by the expression $\{N - x(N-M)\}$ per cent.

At a summit or a valley, the expression is equal to zero;

or
$$x = \left(\frac{N}{N-M}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Thus the distance of a valley or a summit from the tangent-point A is:—

$$\frac{N}{N-M} \times L \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

It is evident that the position and level of the gulley-point in a valley may be readily determined from equations (3) and (1) respectively.

Sight-lines.

Vertical curves form either summits or valleys.

In the design of the former, consideration must be given to: (1) visibility or sight-line; (2) minimum radius of curvature. For valleys, only the second consideration applies.

The following two cases refer to the sight-line afforded by a curve:—

Case 1. When the length of the Sight-Line exceeds the length of the curve. In *Fig. 2*, S denotes the length of the required sight-line FG to the curve

TABLE I.—DATA FOR SETTING OUT PARABOLIC CURVE.

$N = -2{\cdot}75$ per cent. $M = +3{\cdot}25$ per cent. $(N - M) = -6{\cdot}00$ per cent.
Length of curve = 180 feet.

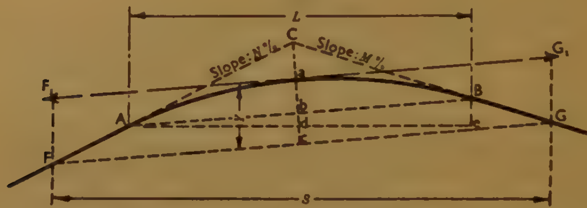
Distance from tangent point A: feet.	$x = \frac{l}{L}$.	$\frac{x}{2}(N - M)$ per cent.	$\left\{N - \frac{x}{2}(N - M)\right\}$ per cent.	$\frac{l}{100}\left\{N - \frac{x}{2}(N - M)\right\}$: feet.	Reduced level: feet.
0	—	—	—	—	155·12
10	$\frac{1}{18}$	− 0·167	− 2·75 + 0·167 = − 2·58	− 10 × ·0258 = − 0·26	154·86
20	$\frac{2}{18}$	− 0·333	„ + 0·333 = − 2·42	− 20 × ·0242 = − 0·48	154·64
30	$\frac{3}{18}$	− 0·50	„ + 0·50 = − 2·25	− 30 × ·0225 = − 0·68	154·44
40	$\frac{4}{18}$	− 0·667	„ + 0·667 = − 2·08	− 40 × ·0208 = − 0·83	154·29
50	$\frac{5}{18}$	− 0·833	„ + 0·833 = − 1·92	− 50 × ·0192 = − 0·96	154·16
60	$\frac{6}{18}$	− 1·00	„ + 1·00 = − 1·75	− 60 × ·0175 = − 1·05	154·07
70	$\frac{7}{18}$	− 1·167	„ + 1·167 = − 1·58	− 70 × ·0158 = − 1·11	154·01
80	$\frac{8}{18}$	− 1·333	„ + 1·333 = − 1·42	− 80 × ·0142 = − 1·14	153·98
90	$\frac{9}{18}$	− 1·50	„ + 1·50 = − 1·25	− 90 × ·0125 = − 1·13	153·99
100	$\frac{10}{18}$	− 1·667	„ + 1·667 = − 1·08	− 100 × ·0108 = − 1·08	154·04
110	$\frac{11}{18}$	− 1·833	„ + 1·833 = − 0·92	− 110 × ·0092 = − 1·01	154·11
120	$\frac{12}{18}$	− 2·00	„ + 2·00 = − 0·75	− 120 × ·0075 = − 0·90	154·22
130	$\frac{13}{18}$	− 2·167	„ + 2·167 = − 0·58	− 130 × ·0058 = − 0·75	154·37
140	$\frac{14}{18}$	− 2·333	„ + 2·333 = − 0·42	− 140 × ·0042 = − 0·59	154·53
150	$\frac{15}{18}$	− 2·50	„ + 2·50 = − 0·25	− 150 × ·0025 = − 0·38	154·74
160	$\frac{16}{18}$	− 2·667	„ + 2·667 = − 0·08	− 160 × ·0008 = − 0·13	154·99
170	$\frac{17}{18}$	− 2·833	„ + 2·833 = + 0·08	+ 170 × ·0008 = + 0·14	155·26
180	$\frac{18}{18}$	− 3·00	„ + 3·00 = + 0·25	+ 180 × ·0025 = + 0·45	155·57

AB. The level of the eye is Y feet above carriageway-level, that is, $FF_1 = GG_1 = Y$.

FG and F_1G_1 will be parallel to the straight line joining AB.

Line Cabc is the bisector of the angle ACB, and point a is there-

Fig. 2.



fore the point of the parabola having minimum radius of curvature. The sight-line will be equally divided by this line at a.

b is the mid-point of AB.

Ae is horizontal and, taking into account the usual road gradients, Cabc may be considered vertical.

Now $$\text{ab} = \text{ad} - \text{bd}$$

and $$\text{ad} = \frac{L}{100 \times 2}\{N - \tfrac{1}{4}(N - M)\}$$

and $$\text{bd} = \frac{L}{100 \times 2}\{N - \tfrac{1}{2}(N - M)\}$$

Therefore $$\text{ab} = \frac{L}{8}\,\frac{(N - M)}{100} \quad \ldots\ldots\ldots \quad (4)$$

Again $$Y = \text{ab} + \text{bc}$$

and $$\text{bc} = \frac{(S - L)}{4}\,\frac{(N - M)}{100}$$

so $$Y = \frac{(N - M)}{4 \times 100}\left(S - \frac{L}{2}\right)$$

that is, $$L = 2\left(S - \frac{4Y \times 100}{(N - M)}\right) \quad \ldots\ldots \quad (5)$$

Case 2. Where the length of the sight-line is less than the length of the curve.

In *Fig. 3* the construction is similar to *Fig. 2*; a is the point of minimum radius of curvature and c is the mid-point of FG.

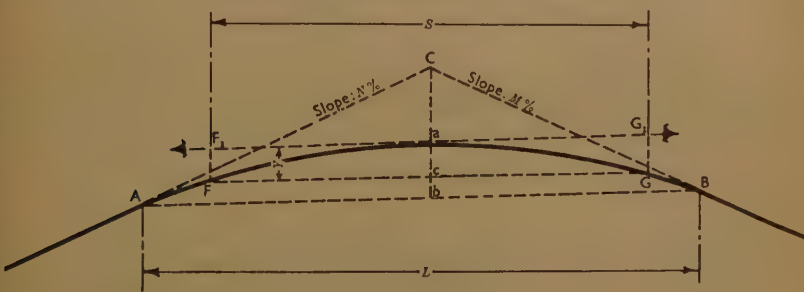
Now n, the slope of the tangent at F $= \dfrac{N}{100} - \dfrac{(L - S)}{2L}\,\dfrac{(N - M)}{100}$

and m, „ „ „ G $= \dfrac{N}{100} - \dfrac{(L + S)}{2L}\,\dfrac{(N - M)}{100}$

Now
$$Y = \text{ac} = \frac{S}{8}\,\frac{(n - m)}{100} \quad \text{(See equation (4)).}$$
$$= \frac{S^2}{8L}\,\frac{(N - M)}{100}$$
or
$$L = \frac{S^2\,(N - M)}{8Y \times 100} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

It is evident that, given the values of N and M and the required sight-line, the length of the suitable curve can be obtained directly from equation (5) or (6).

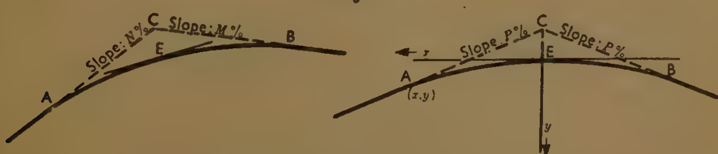
Fig. 3.



Minimum Radius of Curvature.

When a vehicle passes over a vertical parabolic curve, the centrifugal acceleration increases gradually from zero to a maximum when the minimum radius of curvature is reached. Should this maximum acceleration exceed a certain value the occupants of the vehicle will experience an uncomfortable sensation. The value of this acceleration has been found to be approximately 2·5 feet per second per second.

Figs. 4.



Therefore, in the design of a given curve, the minimum radius of curvature must be determined to allow the smooth passage over it of a vehicle at a given speed.

In *Figs. 4* (*a*), E is the point of minimum radius of curvature.

Now, if the length of the curve and the expression $(N - M)$ per cent. remain constant, the curve has a constant form for all corresponding values of N and M.

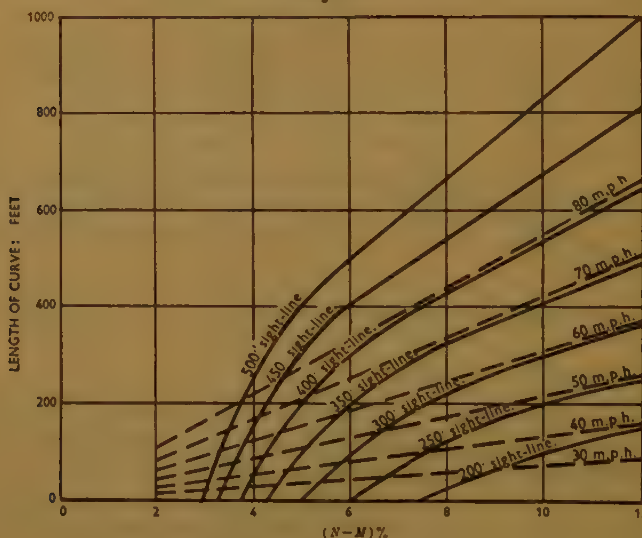
The tangents are therefore turned while keeping the value of $(N - M)$

per cent. constant through an angle such that the bisector of angle ACB becomes vertical. Point E is on this bisector.

The gradients will now have the same numerical value and will be equal to $\frac{(N-M)}{2}$ per cent.; that is, slope P (*Figs. 4* (*b*)) equals $\frac{1}{2}(N-M)$ per cent.

If E (*Figs. 4* (*b*)) be the origin of a graph with axes as shown, then the co-ordinates of the point A are (x, y).

Fig. 5.



The equation of a parabola with these axes is given by the expression $x^2 = 4ay$.

Considering point A, $x = \frac{L}{2}$ and $y = \frac{L}{8}\,\frac{(N-M)}{100}$

Therefore, $$4a = \frac{2L}{(N-M)} \times 100$$

and the minimum radius of curvature $R = \frac{L \times 100}{(N-M)}$ feet . . . . (7)

If the vehicle has a speed of V miles per hour, or v feet per second, then the maximum centrifugal acceleration $a = \frac{v^2}{R}$; therefore $R = \frac{v^2}{a}$.

Assuming the limiting value of a to be 2·5 feet per second per second, then the minimum radius of curvature $R = 0{\cdot}86V^2$ feet . . . . (8)

and the minimum length of curve $L = 0{\cdot}86V^2\dfrac{(N-M)}{100}$ feet . . . (9)

This result is of importance in the design of valleys and vertical curves between flat gradients, where sight-line requirements are satisfied with very short lengths of curves.

The greatest care should be exercised in these cases, since the probable speed of vehicles passing over these curves would be much higher than on steeper gradients.

In *Fig. 5*, lines of constant length of sight-line and constant speed have been drawn. For sight-lines the eye-level has been assumed to be 3 feet 9 inches above the carriageway-level.

From this graph the length of curve to satisfy sight-line or speed requirements can be readily determined.

The Paper is accompanied by five drawings, from which the Figures in the text have been prepared.

OBITUARY.

SIR HARLEY HUGH DALRYMPLE HAY, Kt., was born in India on the 7th October, 1861, and died at Chorley Wood, Herts, on the 16th December, 1940. He was educated at a private school in Edinburgh and by Army tutors, and started his engineering career as a pupil on the South Wales lines of the Midland Railway, becoming later an assistant in the divisional office at Brecon. His next appointment was in the drawing offices of the London and South Western Railway, and in 1894 he was engaged as resident engineer on the Waterloo and City tube railway, in the construction of which he employed his own system of hooded shield and clay pockets for driving the tunnels under compressed air without requiring a heading or timbers outside the shield. In subsequent years he was engaged in the design and construction of the Bakerloo, Hampstead, and Piccadilly tube railways, and was responsible for the new Piccadilly Circus station, which was opened in 1928. In 1902 he was appointed consulting engineer to the London Underground Electric Railways Company. In 1907 he commenced practice as a consulting civil engineer, and also acted in that capacity for the Post Office (London) tube railway. In 1921 he was asked to report on a system of tube railways for Calcutta, and later planned a tunnel under the river Hooghly to carry the cables of the Calcutta Electric Supply Corporation to Howrah: this tunnel, completed in 1931, was the first shield-driven iron-lined tunnel under a great tidal river in the East, and its construction was carried out under high pressures in difficult climatic conditions, and with the use of unskilled labour. More recently he carried out extensions of the London tube railways for the London Passenger Transport Board, and also designed and executed important works for various British corporations. He received the honour of knighthood in 1933.

He was elected an Associate Member of The Institution on the 6th December, 1887, was transferred to the class of Member on the 28th March, 1899, and served on the Council from November, 1933, until his death. As a Student he presented a Paper on "Trigonometrical Surveying"[1], for which he was awarded a Miller prize, and in 1900 he received a Telford gold medal and a Telford premium for his Paper on "The Waterloo and City Railway.[2]"

In 1891 he married Agnes Yelland, daughter of Frederick Waters, and had one daughter.

[1] Minutes of Proceedings Inst. C.E., vol. lxxx (1884–5, Part 2), p. 283.
[2] *Ibid.*, vol. cxxxix (1899–1900), Part 1), p. 25.

ABSTRACTS OF THE CURRENT TECHNICAL LITERATURE OF ENGINEERING AND APPLIED SCIENCE.

ENGINEERING CONSTRUCTION.

Structural Characteristics of Brick Masonry. H. R. Staley (**J. Boston Soc. Civ. Engrs.*, 27, *251–273 ; Oct. 1940*).—The Author discusses some of the factors that have a bearing upon the selection and use of materials for brick masonry, confining himself to those which are important from the structural point of view. He describes a series of tests to investigate the effect upon masonry strength of seven mortars of four different proportions, when assembled with five representative bricks. In building the test-piers the bricks were laid dry, all joints were slushed full, and the face of the joints was struck with a flat pointer. All specimens were moist-cured for 28 days. The piers were 8 inches by 8 inches by 16 inches high, laid up with ½-inch joints. During loading strain-gauge readings were taken at 10,000-lb. increments of load up to 160,000 lb., and thereafter at 20,000-lb. increments. The results are tabulated. The Author discusses the effect of the slenderness-ratio, eccentric loading, volume-changes, efflorescence, and the effect of temperature and moisture changes. He concludes that in order to obtain some of the other desirable characteristics in masonry walls, some sacrifice of strength can be made. The use of adequate strength rather than highest strength is a more desirable procedure. Adequate strength can be obtained by using mortars with at least one part of lime to one part of portland cement. With the use of stronger brick adequate strength can be obtained with mortars higher in lime-content.

The Design of Multi-Span Arch Bridges on Elastic Piers. J. J. Leeming (**J. Instn. Struct. Engrs.*, 18, *723–737 ; Dec. 1940*).—The Author describes a method of design based upon the principle of superposition and the theorem of strain energy, in which the former principle is used to reduce the number of equations to be solved at a time. It does not involve any approximations other than those inherent in the method of summations usual in arch design, and the only restriction as to shape is the assumption that the structure is symmetrical about a vertical

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Notes.—An asterisk prefixed to a reference, thus **J. Boston Soc. Civ. Engrs.*, denotes that the article is illustrated.

The abbreviated titles of periodicals are those used in the "World List of Scientific Periodicals" (Oxford, 1934).

centre-line. The method is stated to be equally applicable to arch or portal frame type bridges, to roof principals, and to structures of any shape, provided that they are of more or less arched form, so that there will be some thrust; and that they conform to the assumption of symmetry. Detailed examples of the application of the method to symmetrical frames are described, and the Author states that similar reasoning can be adopted in regard to unsymmetrical frames.

Bascule Bridge at Lorain, Ohio. (**Engng. News-Rec.*, 125, *742–744; 5 Dec. 1940.*)—The low swing-bridge at Lorain, Ohio, has been replaced by a four-lane double-leaf bascule bridge, 333 feet between centres of the trunnion pins. The clear ship-channel is 180 feet wide, on account of the skew of the roadway with the river; a 33-foot vertical clearance is provided near the centre-line of the closed bridge. Owing to the proximity of the old bridge during construction, working room was restricted, and the operating machinery had to be located within the piers immediately below the trunnion bearings. As this reduced the available room for counter-weight, "heavy" concrete, incorporating hematite iron-ore as fine and coarse aggregate was utilized. Descriptions are given of the operating machinery, of the foundations, and of the construction procedure.

The Sterilization of Repaired Water Mains. Lt.-Col. E. F. W. Mackenzie (*Water & Water Engng.*, 42, *394–398; Dec. 1940*).—The Author observes that considerable experience has been gained with regard to the effects of high-explosive bombs upon water-mains and the possibility of contamination of the mains and of the water remaining in them. He cites numerous instances of damage and expresses the belief that the only safe policy is to assume pollution throughout the whole of the isolated portion of the main. He describes the general scheme of sterilization, formulated before or shortly after the outbreak of war, and states that it has proved satisfactory so far. Mains are divided into two classes, namely small (less than 12 inches in diameter) and large; the method of treatment for each class is described. The Author also describes the mobile chlorinator plant which is employed, indicates the procedure, and presents results of the treatment.

Measurement of Water-Flow at the Safe Harbor Hydro-Electric Power-Station, Pennsylvania. J. M. Mousson (**Power*, 84, *650–652; 708–710; Oct. and Nov. 1940*).—When construction of the Safe Harbor plant was commenced, in 1930, provision was made in the substructure, the generator-room floor, the conduit system, and the control-room, for the inclusion of water-metering equipment; but the time required for research work to develop suitable equipment delayed its installation until late in 1938. The Author describes the piezometer investigations and the calibration procedure, and gives a diagram of the type of flow-meter

selected. He also describes the installation of the flow-meter units in the power-station, and gives the results obtained. These data were used to investigate unit and station efficiencies, and it is estimated that the resulting improvement in operation will increase the station output by approximately 1,700,000 kilowatt-hours per annum, so that the flow-meter equipment will pay for itself within a very short period. The installation also includes an automatic and instantaneous load-limit-indicating apparatus which provides information as to the most efficient loading of the hydro-electric units in the power-station.

Regime Flow in Incoherent Alluvium. GERALD LACEY (**Pub. Central Board Irrig., India, No. 20, 65 pp.; 18 July 1940*).—In this publication the Author has collated his researches made over a period of many years. The work is presented under the following headings: the Kennedy and Lindley theories; regime as a physical concept; correlation of the hydraulic mean depth with the mean velocity and water surface slope; a general regime equation; derivation of a new flow equation and computation of numerical coefficients; alluvial channel shape; derivation of the wetted perimeter-discharge relationship; the Punjab Research Institute equations; a new theory correlating turbulence, bed silt grade, and shock; correlation of the silt factor and bed silt grade in coarse material; dimensional analysis; conclusions. The Author observes that the evidence for regime theory consists of the mass of the data, and not on the mass of channels in regime. Such data are presented in numerous graphs and in ten Appendixes; they cannot be summarized in an abstract.

Anti-Malaria Drainage. J. E. BACH (**J. Engng. Assoc. Malaya*, 8, *83–99; Aug. 1940*).—The Author reviews the development of subsoil drainage for the prevention of malaria, and the experimental work carried out from 1910 onwards in Malaya, and describes the activities of the Malaria Advisory Board, which was formed at Kuala Lumpur in 1914. He also deals with the protection of the labour force and staff during the construction of the Shing Mun ("Gorge") dam in Hong Kong Colony[1], and describes the siting and construction of the drainage channels. He discusses the conditions existing at Ipoh, indicates the advantages derived from suitable drainage, and describes the distinguishing characteristics of anopheline and other mosquitoes.

MECHANICAL ENGINEERING.

A Large All-Welded Electric Motor. (**Elect. Rev.*, 128, *7; 8 Nov. 1940.*)—By the fabrication of a 1,900-horse-power, three-phase motor from steel plates with the aid of oxy-coal-gas cutting and electric

[1] *See also* W. J. E. Binnie and H. J. F. Gourley, "The Gorge Dam," Journal Inst. C.E. vol. 11 (1938–9), p. 179; Mar. 1939.

arc welding, important savings have been effected in production costs, together with economy in materials, a reduction in manufacturing time, and increased rigidity and strength in comparison with castings. The machine, of the synchronous-induction type, is 16 feet long by 14 feet high, and weighs 40 tons. It is designed to operate at unity power-factor on a 50-cycle, 11-kilovolt circuit, and is similar in construction to a slip-ring induction motor, except for a larger air-gap to ensure synchronous stability and more rotor copper to reduce losses. Self-ventilation is effected by paddle-type fans and air-deflectors on the rotor. Details are given of the frames and windings of the stator and rotor, and of the starting system.

New High-Voltage Laboratory at Liverpool University. (**Electrician*, 125, *297–298 ; 6 Dec. 1940.*)—The new laboratory, opened on the 29th November, 1940, is equipped with a 1-million-volt impulse generator of a new type, with a 1-metre gap, arranged above the condensers, for measuring the impulse voltage. A pit 10 feet by 6 feet and 3 feet deep was made to provide additional headroom for the gap. The condensers are arranged in eight sections, each of 0·2 microfarad capacitance : they are charged to 125 kilovolts from a high-voltage transformer supplying direct current through a two-stage voltage-multiplier, and are discharged in series, the series-connexion being effected by spark-gaps, as in the standard Marx generator. A cathode-ray oscillograph is used for measuring purposes. The laboratory equipment also includes a high-frequency, high-voltage testing plant which enables voltages of 80 kilovolts at frequencies of 500 to 1,000 kilocycles to be obtained, and a 300-kilovolt transformer, rated at 150 kilovolt-amperes.

Mechanical Integrity in the Design of Electrical Circuit-Breakers. M. C. Hunter (**J. Instn. Elec. Engrs.*, 87, *665–672 ; Dec. 1940*).—The Author discusses the mechanical requirements of circuit-breakers and suggests methods of design to meet them and to guard against imperfections which may arise during manufacture. He describes the effects of various forms of contacts upon the frictional characteristics of circuit-breakers, and observes that, judging by the many diverse forms of contacts in use, no design of a breaker can be commenced without full data in regard to the contact characteristics. He suggests a series of practical routine tests to ensure that the calculated design factors are complied with, and emphasizes the importance of accuracy in workmanship.

New Locomotives for the New York Central Railway. (**Rly. Age, Chicago*, 109, *856–861 ; 864 ; 7 Dec. 1940.*) Deliveries are now being received of fifty locomotives of the 4–8–2 type. Although designed primarily for goods service, half of the number are being completely equipped for passenger service and will serve both types of traffic. The boilers are of the conical type, of $82\frac{7}{16}$ inch internal diameter at the

first course and 94 inches outside diameter at the largest course: they are designed for a working pressure of 255 lb. per square inch: all inside seams are welded. The engines are fitted with single-loop superheaters with throttles integral with the headers. The heating-surface of the tubes and flues is 4,284 square feet; of the superheaters 2,080 square feet; and of the firebox and combustion chamber 373 square feet. The weight on the driving-wheels is 262,000 lb. in the case of the combined passenger and goods engines, and 265,000 lb. for the engines intended for goods service only; the respective total weights of the engines are 388,500 lb. and 393,500 lb. The tenders have a water-capacity of 15,500 (U.S.) gallons and a fuel-capacity of 43 tons. Boosters are fitted only on the goods locomotives.

The Machining of Abrasive Timber. P. Harris (**Engng., Lond.*, **150**, *501–502; 27 Dec. 1940*).—The Author describes a research made at the Forest Products Research Laboratory to investigate the mechanism of blunting of wood-cutting tools, and its relation to cutting and feeding speeds, tool-shape, and other factors, and also to determine the influence of the rate of feeding upon cutter-wear and energy-consumption in planing. The timber used was Queensland walnut, and the cutters were thin high-speed steel knives of best quality, fitted in a power-fed planing-machine, at standard values of cutting-angle and grinding-angle, and with various feed-speeds. The results are plotted in curves. The conclusions are summarized as follows: the wear on a cutter is caused through the initial rubbing of the cutting-edge before complete entry into the wood and that occurring under the intense pressure needed for the separation and deflexion of the chip; the best output from a cutter, before re-sharpening is necessary, can be obtained by minimizing the initial rubbing and arranging for the maximum quantity of wood to be removed at each cut, and by using feed-speeds as rapid as the finish and capacity of the machine permit; the use of high feed-speeds in machining abrasive material provides longer service from tools, increased production, and reduced energy-consumption.

The Manufacture of Large Drums for Water-Tube Boilers. P. W. McGuire (**Trans. Inst. Mar. Engrs.*, **52**, *195–200; Nov. 1940*).—The Author describes the "Chesterfield" process for the manufacture of hollow forgings as used for the drums of water-tube boilers. A hot solid steel billet is placed in a circular bush and is punched vertically so as to leave a solid end on the bottom of the resulting bloom; this bloom after having been withdrawn from the punching press, is put on a bar on a horizontal draw bench, and is pushed through dies to reduce the thickness as required, giving a forging of dimensions suitable either for immediate use or for machining to finished sizes. The heat treatment of the drum —annealing, normalizing, and stress-relieving—is also described, and detailed test results are given.

The Weldability of High-Tensile Structural Steels. L. Reeve (*Trans. Inst. Welding*, 3, *177–202 ; Oct. 1940*).—In the report of a sub-committee of the Institute, the Author presents the results of a series of tests made with the object of determining the correct procedure for the successful welding of certain high-tensile steels. The studies were made on plates ½ inch and 1 inch thick, of eleven steels, the compositions of which are tabulated, and included tensile, bending, and impact tests, standard Reeve crack tests, quench hardening tests on tapered specimens, gas-cutting tests, and corrosion tests. The results are given in Tables and curves; they indicate that only six of the types of steel tested can be regarded as fully weldable, that is, as having a complete absence of welding cracking in the plate independently of the size of weld deposited. None of the steels which comply with British Standard Specification No. 548 (37–43 tons tensile), can be regarded as fully weldable on the basis of these tests, although when suitable precautions are taken they can be welded successfully.

Temporary Metering: Unusual Methods giving Exact Results. G. W. Stubbings (**Elect. Rev.*, 128, *31–32 ; 15 Nov. 1940*). The Author describes five temporary metering schemes for electric supply, which are stated to yield results comparable in accuracy with those obtainable from meters of normal design. These are respectively for the measurement of a three-wire direct-current supply; a three-phase four-wire supply; and a three-phase four-wire supply when a number of disused single-phase three-wire meters are available; connexions for an ordinary three-phase meter so that it will accurately register reactive kilovolt-ampere-hours; and a method of measuring kilowatt-hours and reactive kilovolt-ampere-hours in a three-phase four-wire load.

MINING ENGINEERING.

Machine Mining in Wartime: Recent Developments in Mechanization. (**Iron Coal Tr. Rev.*, 161, *567–587 ; 6 Dec. 1940.*) In a series of brief articles information is given regarding recent machine-mining installations in Great Britain and experience gained with apparatus which has already been in operation for some time. These include descriptions of a new bottom-belt conveyor at a Derbyshire colliery; experience with steel props at a Staffordshire colliery; the method of developing the Banbury seam at a North Staffordshire colliery; details of a new method of cutting steep seams; the development of the Bench seam of coal in a Staffordshire mine by means of a caving system using shock releases; details of the mechanical equipment for working the deep soft coal in a Nottinghamshire colliery; experience in drilling stone with a rotary drill; unusual conveyor

installations at two Derbyshire collieries; the use of a pneumatic pick in working the Black Bed seam at a Yorkshire colliery; the development of longwall faces; and a description of the automatic coal-washing plant, using Baum boxes, at a Scottish colliery.

The Infrasizer and the Superpanner. W. R. Jones (**Bull. Inst. Min. & Metallurgy, No. 431, 3 pp.; Aug. 1940*).—Two types of apparatus for the sizing and separation of finely-pulverized minerals are described. The infrasizer is a mechanical air elutriator by means of which material, such as ore, ground to minus 200 mesh, can be split into seven separate fractions, each of different grain-size. The finest fraction is less than 10 microns, and under certain conditions less than 5 microns in diameter. The apparatus consists of six tubes, five of which are conical and one parallel-sided, whilst at the air exit a bag of special material catches the finest particles. The diameters of the tubes vary as the square root of 2; thus the average diameter of succeeding products varies as the square root of 2, as in the Tyler series. The adhesion of the fine particles to each other is prevented by a cone and ball device. The air-borne particles impinge on the ball and pass in a thin high-velocity stream between the ball and its rubber seat. The ball is continually rotating and wobbling, thus preventing agglomeration of the particles. The material slides down the sides of the sorting columns, where it is subjected to the scrubbing action of the jets of air around the ball. The function of the superpanner is to separate minerals of different specific gravities.

An Automatic Control for Washboxes. (**Colliery Engng.*, 18, *5–9; Jan. 1941.*)—Detailed descriptions are given of two coal-washeries, of the Baum or jig-type box and the feldspar box type respectively. The former box, which is in operation at one of the collieries of Dalton Main Collieries, Ltd., washes 100 tons per hour of coal below 2-inch size, and prior to its conversion was controlled by hand. Conversion to automatic operation merely involved the installation of a self-acting shale, remover at each end, and adjustment of the timing of the pulsations. The feldspar washer is in service at one of the pits of Amalgamated Denaby Collieries, Ltd. The plant is required to wash peas below $\frac{7}{16}$ inch, and the box which has been converted is capable of dealing with 40 tons per hour. The results obtained from these two conversions are tabulated, and it is stated that they are being consistently maintained. Average results obtained from other washeries are also given. The consistency of washing realized enables the maximum quantity of middlings to be included in the washed coal without exceeding the guaranteed ash-content in the product as sold. A Table of operating results indicates an increase in the yield of good coal of about 200 tons per week.

Shaft Signalling. H. A. Walker (**Min. Congr. J.*, 26, *20–24; Sept. 1940*).—The Author describes the "carrier-current" system of signalling recently installed in a new shaft, which enables direct vocal or bell signals to be transmitted from a cage, stationary or moving, to the winding-engine operative, or from the latter to the cage-tender. A modification of the carrier-current system is employed to give an automatic visual signal during winding operations, showing whether the cage is on or off the chairs.

Note.—The Institution as a body is not responsible either for the statements made, or for the opinions expressed, in the Papers and Abstracts published.

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NOTICES

No. 4, 1940—41

FEBRUARY, 1941

MEETINGS, SESSION 1940–41.

ORDINARY MEETINGS.

The following subjects will be brought forward for discussion at Ordinary Meetings, on the dates shown below :—

1941.

Feb. 18.* (1.30 p.m.) **"Further Data Concerning Pre-stressed Concrete: Comparison between Calculated Stresses and Stresses registered during Tests,"** by T. J. Gueritte, B.Sc. (Jointly with the British Section of the Société des Ingénieurs Civils de France.)

There will be a ballot for the election of new members.

* An abstract of this Paper appears at p. [9], of the January Journal.

Mar. 18.** (1.30 p.m.) **"Aesthetics of Engineering Structures"**, by Oscar Faber, O.B.E., D.C.L., D.Sc., M. Inst. C.E.,

and

"The Design of Flour Mills, Granaries, Warehouses and Silos", by Oscar Faber, O.B.E., D.C.L., D.Sc., M. Inst. C.E.

There will be a ballot for the election of new members.

** Abstracts of the Papers appear at pp. [9], [10], *post.*

(*Light refreshments will be served at* 12.30 *p.m.*)

JAMES FORREST LECTURE.

The James Forrest Lecture will be delivered on Tuesday, 29 April, at 1.30 p.m., by Dr. C. G. Darwin, M.C., M.A., F.R.S. The title of the lecture will be announced in the March Journal.

ANNUAL GENERAL MEETING.

The Council, acting upon the powers conferred upon them, have decided that the Annual General Meeting of Corporate Members shall be held on Tuesday, 27 May, at 1.30 p.m.

SPECIAL ANNOUNCEMENTS.

RECORD OF SERVICE IN THE FORCES.

For office purposes, a record is being kept of members' service with H.M. Forces, and members who have not already done so are asked to inform the Secretary of such service, i.e. unit, rank, promotions, decorations, etc. Further, practical use is made of such information when inquiries from the Services are received by The Institution.

MILITARY SERVICE. MINISTRY OF LABOUR.

Details of the following appear on pp. [2]–[5] respectively of the December, 1940, Number of the Journal :—

Vocational instruction for those temporarily serving in H.M. Forces (p. [2]).

Registration in the Army Officers' Emergency Reserve; special enlistment in the Royal Engineers; and entry into the ranks of the Royal Engineers under the National Service (Armed Forces) Act, 1939 (p. [4]).

An entry in the Ministry of Labour's Schedule of Reserved Occupations as affecting "student engineering apprentices or learners" who wish to sit for Sections A and B of the Associate Membership Examinations, together with information as to the procedure to be adopted by Corporate Members of The Institution who are required to register at Local Employment Exchanges when their age-groups are called up under the National Service (Armed Forces) Act, 1939 (p. [5]).

ROYAL MARINE ENGINEERS.

I. Corporate Members who desire to be considered for Commissions, for which there are a limited number of vacancies, in the Royal Marine Engineers, a Corps engaged on Admiralty works ashore, should at once notify the Central Register of the Ministry of Labour and National Service, 41 Tothill Street, Westminster, S.W.1, quoting in their letters "Ref. No. E.64." Applicants must be about 33 to 40 years of age, and have had wide experience on actual constructional work—preferably on harbours, docks, and temporary structures.

II. There are also a limited number of vacancies in the same Corps for subalterns. Students and Corporate Members who desire to be considered for these Commissions should at once notify the Central Register (at the address given above), in this case quoting in their letters "Ref. No. E.101." Applicants must be about 23 to 30 years of age, and have had experience on actual constructional work—preferably on harbours, docks and temporary structures.

AIR MINISTRY.

ENGINEER AND OTHER TECHNICAL OFFICERS REQUIRED BY THE ROYAL AIR FORCE.

Vacancies still exist in the Royal Air Force for technical officers for employment on engineering, armament and signals duties. The following minimum qualifications are required :—

Engineer.

(i) Holders of mechanical engineering degrees, or

(ii) Holders of mechanical engineering certificates, or mechanical engineer members of engineering institutions who also have two years' practical experience, or

(iii) Practical engineers who have served an apprenticeship followed by a number of years' experience in erecting or overhauling internal combustion engines or aeroplane structures, and with knowledge of the properties of engineering materials.

[Students and Corporate Members of The Institution who are desirous of offering themselves as applicants for Commissions as Engineer Officers are required to note that, according to information received from the Air Ministry, the standard of theoretical heat-engine knowledge required of degree men approaches degree standard and that practical men are required to have expert practical knowledge of internal-combustion engines : as regards knowledge of the properties and testing of engineering materials, this is not expected to be of metallurgical degree standard.]

Armament.

(i) Holders of engineering degrees or engineering certificates or members of engineering institutions with at least two years' practical experience, particularly those with experience in armament manufacture, or

(ii) Practical engineers who have served an apprenticeship followed by a number of years' practical engineering experience and with knowledge of the properties of engineering materials.

Signals.

(i) Holders of electrical engineering or science degrees with experience of wireless, or

(ii) Holders of technical college or approved institution diplomas and two years' experience in telecommunications engineering (preferably on the radio side).

A number of posts is also available for candidates possessing a sound theoretical knowledge of elementary electricity and magnetism, of the principles of wireless telegraphic and telephonic communications and of transmitter circuits, modern wireless receiving apparatus, and apparatus

for the measurement of high-frequency potentials and currents. Some practical experience in addition is desirable, and specialized knowledge in one or more of the practical aspects of telecommunications would be an asset.

Commissions in the R.A.F.V.R. will be granted for the duration of hostilities to suitable applicants between the ages of 21 and 50 years possessing the requisite personal and technical qualifications.

The appropriate form of application (No. 1020), and notes on conditions of service, may be obtained from the Secretary of The Institution or from the Air Ministry, S.7.e/5, Adastral House, Kingsway, W.C.2.

The Secretary will be pleased to furnish certificates of membership of The Institution for attachment to applications.

Those who are engaged on the production of aircraft, engines or accessories, or on other important National Work, should not submit applications without first consulting their employers as to the possibility of their being spared for R.A.F. duty.

Candidates who have previously applied are requested not to renew their applications.

GENERAL ANNOUNCEMENTS

ELECTION OF COUNCIL.

The Council give notice that in selecting the names of Corporate Members to appear on the Balloting-List for the election of the Council for the year 1941–42, in accordance with the provisions of the By-Laws, they will be pleased to consider any names which may be suggested by individual Corporate Members, provided that the names are communicated to the Secretary on or before Saturday, 1 March.

The consent of each person proposed must first be obtained by the Corporate Members submitting names, and they must also state the occupation of the person proposed, namely, whether in practice, or holding an official position, or in other employment.

THE JOURNAL.

The next Number of the Journal will be published on the 15th March.

INVITATION TO PRESENT SHORT PAPERS.

The Council are prepared to receive short Communications of, say, 2,000 words, accompanied by two or three illustrations, for inclusion in the Journal. Such Communications should be topical in character and might deal, for example, with demolition and reconstruction problems, or with minor constructional details, of a novel character, which would be of general interest to engineers.

"INGENUITY" COMPETITION.

Papers are invited from Corporate Members and Students in competition for a Prize of Twenty-five Guineas to be awarded by the Council for a description of an engineering problem and the method adopted to solve it.

The article should not exceed 2,000 words, and must describe a specific problem involving immediate action and ingenuity displayed in meeting it. The problem must have arisen in the competitor's own experience, and the action taken must have been to some extent—not necessarily wholly—his own idea. These facts must be vouched for in a satisfactory manner.

The Papers should reach the Institution by the 30th April, 1941, with the MS. marked "Ingenuity" Competition in the top left-hand corner of the first page.

The Council reserve the right to publish the winning entry, or any other selected entries, and should such entries relate to engineering problems arising out of the war, The Institution would submit them to the Censor for permission to publish.

HONOURS.

The Council have much pleasure in congratulating the following Corporate Members on the Distinctions conferred upon them :—

Knights Bachelor :—

	BRISTOW, Robert Charles, C.I.E.	*Member.*
	MOUNT, Lt.-Col. Alan Henry Laurence, C.B., C.B.E., R.E. (ret.)	,,

Order of the Indian Empire :—

C.I.E.	BROMAGE, John Aldhelm Raikes	*Member.*
	DOWLEY, Francis Michael Walshe	,,

Order of the British Empire :—

C.B.E.	HOGG, William Edward	*Member.*
	MANZONI, Herbert John Baptista	,,
O.B.E.	FORD, Ernest Hope	,,
	WEBB, Herbert Marston, M.C., B.Sc.	,,
	HALLAS, George Spencer, M.C., B.Eng.	*Associate Member.*
	MURRELL, William Lee, B.C.E.	,, ,,
	PIERSON, Reginald Kirshaw, M.B.E., B.Sc.	,, ,,
	THOMSON, Ronald Ord Campbell	,, ,,
	WYLIE, Alexander Forrest	,, ,,

EXAMINATIONS.

DATES FOR EXAMINATIONS TO BE HELD IN 1941.

The Preliminary Examination is now replaced by the Common Preliminary Examination, which will be conducted by the Engineering Joint Examination Board.

The conditions of entry for this Examination, and the latest dates for entry will be the same as for the Preliminary Examination which it replaces.

Further information may be obtained on application to the Secretary.

The following dates have been fixed for the Examinations to be held in 1941.

Common Preliminary Examination.	*Associate Membership Examination.*
April the 1st to the 4th inclusive.	April the 21st to the 25th, inclusive.
October the 7th to the 10th, inclusive.	October the 13th to the 17th, inclusive.

The April, 1941, Examinations will be held in London and the Provinces. Intending candidates are reminded that applications to attend should reach the Secretary's hands by the 28th February and that Students of The Institution entering for the Associate Membership Examination are recommended to lodge their applications a fortnight before that date.

C. C. LINDSAY CIVIL ENGINEERING SCHOLARSHIPS.

Regulations for the award of these Scholarships, sanctioned by the Board of Education, may be obtained on application to the Honorary Secretary of the Glasgow and District Association (Mr. William MacGregor, B.Sc., Engineering Department, The University, Glasgow, W.2). Eligibility for the award of these scholarships, which are each of the value of not less than £25 per annum, is confined to Students of The Institution who are members of the Glasgow and District Association of The Institution and are British subjects of Scottish parentage.

TRANSFERS, ELECTIONS, AND ADMISSIONS.

Since the 17th December, 1940, the following elections have taken place :—

Meeting.	*Associate Members.*
21 January, 1941.	49

and during the same period the Council have transferred four Associate Members to the class of Members, and have admitted seventy-six Students.

DEATHS AND RESIGNATIONS.

The Council have received, with regret, intimation of the following deaths and resignations :—

Deaths.

Brown, Cuthbert, M.B.E. (E. 1901. T. 1923.)	*Member.*
Coode, Arthur Trevenen, B.A. (E. 1902. T. 1912.)	,,
Miller, Harry William. (E. 1893. T. 1930.)	,,
Craig, Walter Lennox, B.C.E. (E. 1901.)	*Associate Member.*
Ellison, David. (E. 1905.)	,, ,,
Lipscomb, Herbert Nicholson. (E. 1890.)	,, ,,
Lloyd, Frederick Charles Lyndon. (E. 1928.)	,, ,,
Robertson, Ian Donald. (E. 1913.)	,, ,,
Spooner, Henry John. (E. 1885.)	,, ,,
Wood, Alphonse. (E. 1905.)	,, ,,

Lawrence, John Helm, B.Sc.Tech. (A. 1936.)	*Student.*
MacDonald, Thomas Edward. (A. 1935.)	,,

Resignations.

Ashley, Herbert. (E. 1899. T. 1905.)	*Member.*	
Gott, *Sir* Charles Henry. (E. 1898. T. 1906.)	,,	
Gregory, Reginald Victor, B.Sc. (E. 1912. T. 1929.)	,,	
Livesey, Frank, B.A. (E. 1908. T. 1922.)	,,	
Pollitt, Harry. (E. 1894. T. 1899.)	,,	
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ABSTRACTS OF PAPERS FOR DISCUSSION.

The following Papers will be brought forward for discussion on the date indicated in the margin of the abstracts, and will be published, with reports of the oral and written discussions upon them, in the Journal. Members desiring to take part in the consideration of the Papers should apply forthwith for advance copies, which will be forwarded as soon as they are ready. Applications for proofs should be made on postcards, quoting the numbers of the Papers.

A period of about 3 months from the date of publication of the Papers in the Journal is generally allowed for written communications, which should be :—

(*a*) As concise as possible and entirely relevant to the subject-matter of the Paper ;
(*b*) Written legibly or typed with the lines openly spaced.

(*Paper No. 5264*)

Date of Discussion 18/3/41

"Aesthetics of Engineering Structures."

By Oscar Faber, O.B.E., D.C.L., D.Sc., M. Inst. C.E.

Engineers must conform to the reasonable demand that our cities shall be built with considerations of beauty and harmony, and that engineering structures, forming, as they do, important elements in our civilization, must conform to the same requirements and be things of beauty.

If this aspect of their work were lost, the public would remove from the control of such engineers the design of important engineering structures.

This aspect of the engineer's work is inadequately dealt with in the curricula of engineering colleges, and young engineers receive little training in this part of their work.

The Author suggests that an engineering structure must satisfy four main requirements to be really satisfactory. It must fulfil all its functional requirements, be sufficiently permanent, sufficiently economical, and must give aesthetic satisfaction.

The Paper deals with the things which go to determine whether the latter requirement will be met, and shows that the four main requirements are harmony, composition, character, and interest. These, in turn, depend on the proper handling of masses, colour, texture, rhythm, silhouette, expression of purpose, and expression of construction.

Date of
Discussion
18/3/41

(*Paper No. 5265*)

" The Design of Flour Mills, Granaries, Warehouses, and Silos."

By Oscar Faber, O.B.E., D.C.L., D.Sc., M. Inst. C.E.

A description is given of a large warehouse erected for the Southern Railway for the most economic and labour-saving handling of grain in sack, as well as general goods of all kinds delivered by water or by rail to the warehouse, and delivered therefrom by rail or road.

The handling appliances, as well as the construction of the building, are described, and are illustrated with drawings and photographs.

A description is given of several modern silo buildings in which grain is stored in bulk in bins about 100 feet high, exclusive of the conveyor floor at the bottom for out-loading and at the top for in-loading, and of the modern methods of handling grain in bulk.

A description is given of two modern flour mills complete with silos, mill building, and warehouse, and the arrangement as well as the construction of the buildings is described and illustrated with photographs.